Rules and Regulations for the Classification of Special Service Craft

July 2021

Lloyd's Register

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A guide to the Rules

and published requirements

Rules and Regulations for the Classification of Special Service Craft

Introduction

The Rules are published as a complete set; individual Parts are, however, available on request. A comprehensive List of Contents is placed at the beginning of each Part.

Rules updating

The Rules are generally published annually and changed through a system of Notices between releases.

Rules programs

LR has developed a suite of Calculation Software that evaluates Requirements for Ship Rules, Offshore Rules, Special Service Craft Rules and Naval Ship Rules. For details of this software please contact LR.

Direct calculations

The Rules may require direct calculations to be submitted for specific parts of the ship structure or arrangements and these will be assessed in relation to LR's own direct calculation procedures. They may also be required for ships of unusual form, proportion or speed, where intended for the carriage of special cargoes or for special restricted service and as supporting documentation for arrangements or scantlings alternative to those required by the Rules.

July 2021

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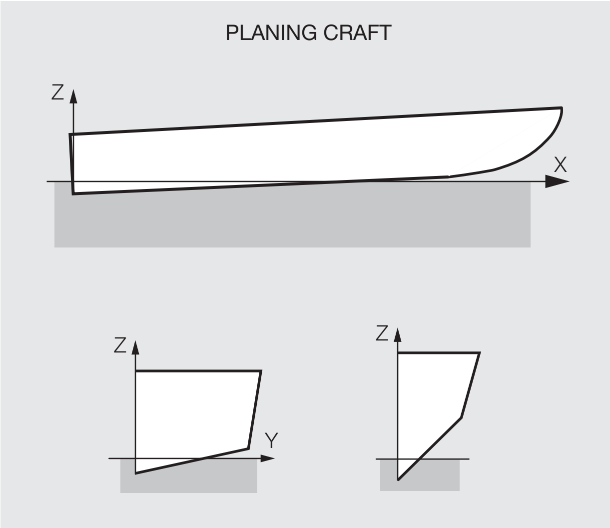
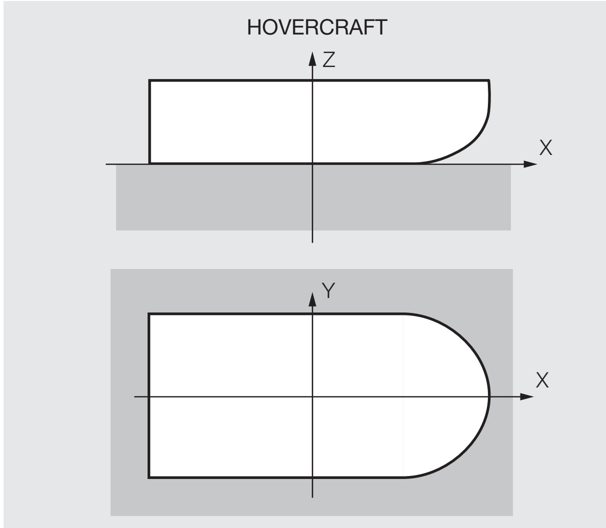
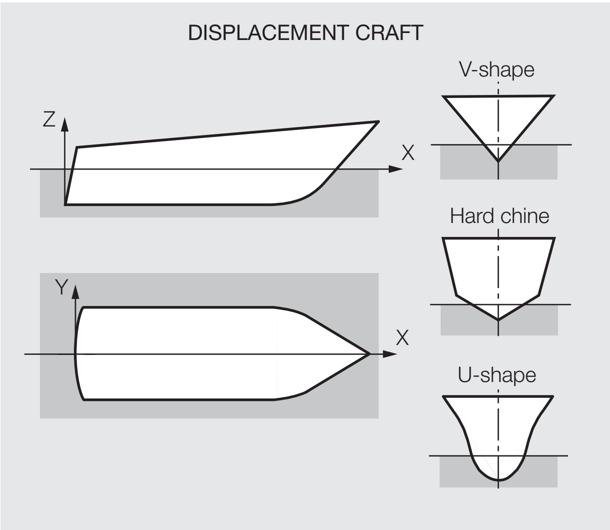
DIFFERENT TYPES OF HULL FORMS COVERED BY THE SPECIAL SERVICE CRAFT RULES



PLANING CRAFT



HOVERCRAFT



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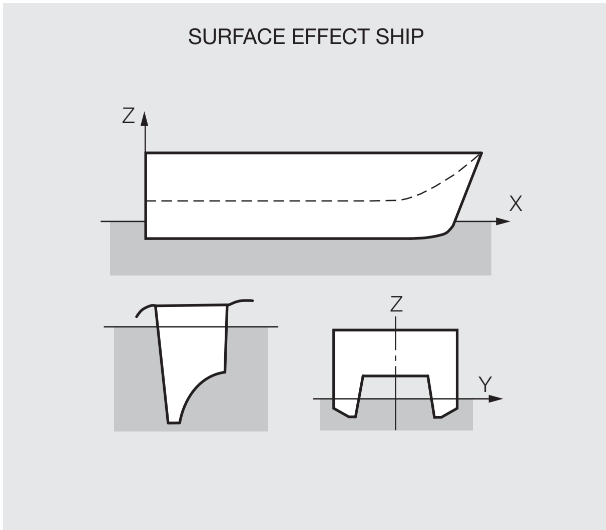
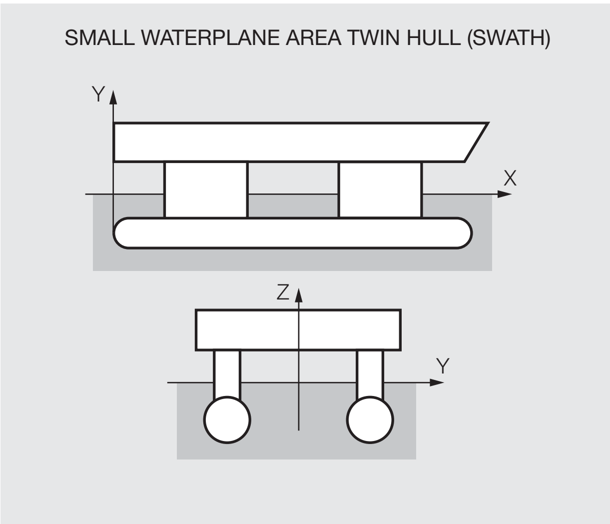
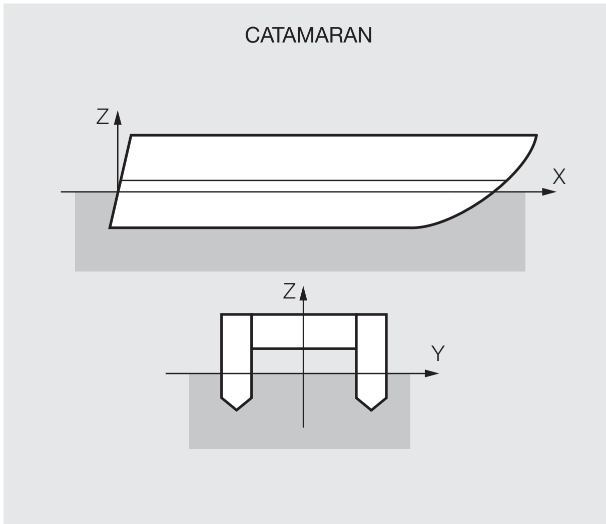


SURFACE EFFECT SHIP

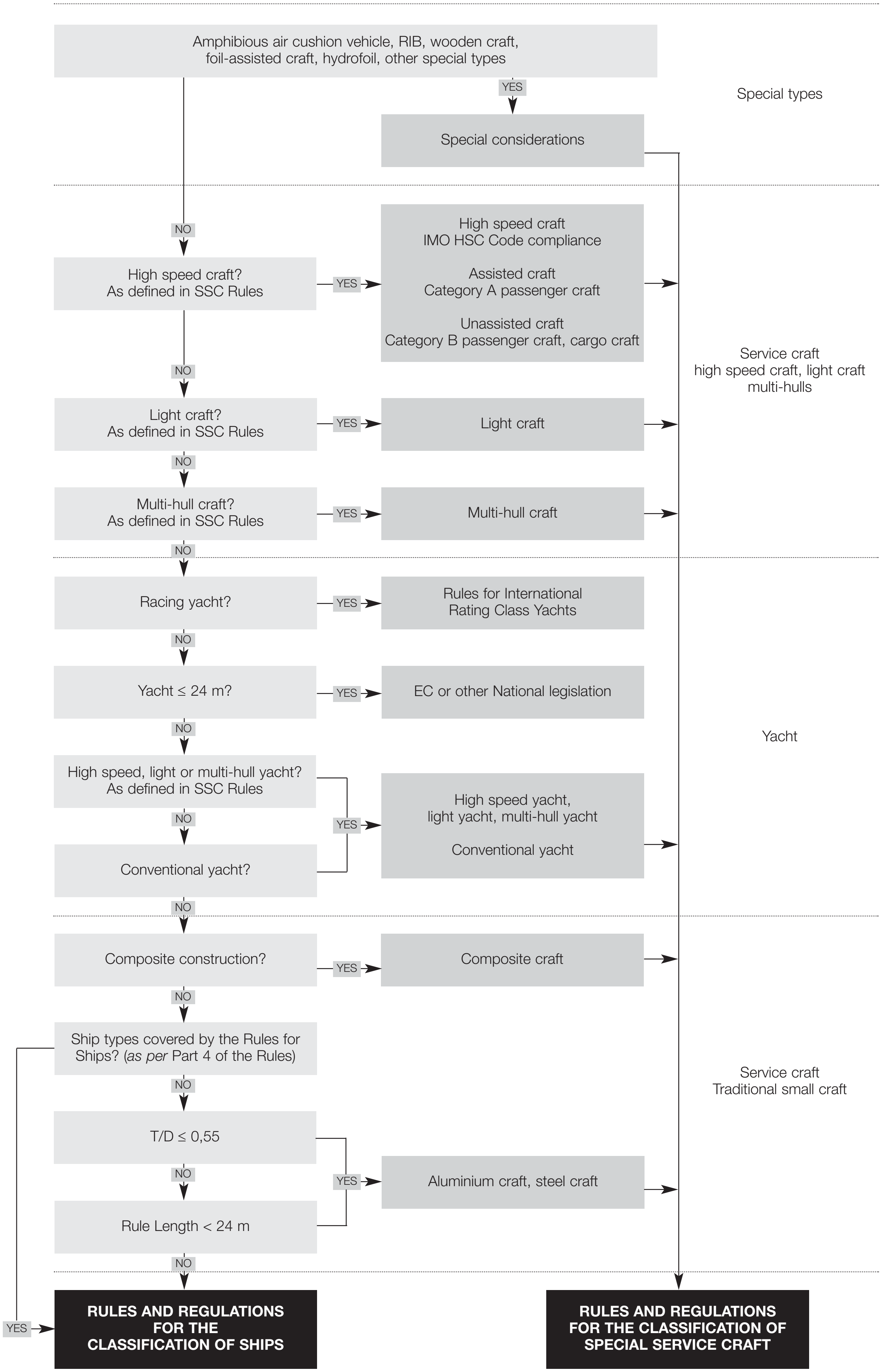


SMALL WATERPLANE AREA TWIN HULL (SWATH)



CATAMARAN

DIFFERENT TYPES OF CRAFT COVERED BY THE SPECIAL SERVICE CRAFT RULES



■ *Section 1* Background

1.1 Lloyd's Register Group Limited is a registered company under English law, with origins dating from 1760. It was established for the purpose of producing a faithful and accurate classification of merchant shipping. It now primarily produces classification Rules.

1.2 Classification services are delivered to clients by a number of other members subsidiaries and affiliates of Lloyd's Register Group Limited, including but not limited to: Lloyd's Register EMEA, Lloyd's Register Asia, Lloyd's Register North America, Inc., and Lloyd's Register Central and South America Limited. Lloyd's Register Group Limited, its subsidiaries and affiliates are hereinafter, individually and collectively, referred to as 'LR'.

■ *Section 2* Governance

2.1 Lloyd's Register Group Limited is managed by a Board of Directors (hereinafter referred to as 'the Board').

The Board has:

appointed a Classification Committee and determined its powers and functions and authorised it to delegate certain of its powers to a Classification Executive and Devolved Classification Executives;

appointed Technical Committees and determined their powers, functions and duties.

2.2 LR has established National and Area Committees in the following:

Countries:	Areas:
Australia (via Lloyd's Register Asia)	Benelux (via Lloyd's Register EMEA)
Canada (via Lloyd's Register North America, Inc.)	Central America (via Lloyd's Register Central and South America Ltd)
China (via Lloyd's Register Asia)	Nordic Countries (via Lloyd's Register EMEA)
Egypt (via Lloyd's Register EMEA)	South Asia (via Lloyd's Register Asia)
Federal Republic of Germany (via Lloyd's Register EMEA)	Asian Shipowners (via Lloyd's Register Asia)
France (via Lloyd's Register EMEA)	Greece (via Lloyd's Register EMEA)
Italy (via Lloyd's Register EMEA)	

Japan (via Lloyd's Register Group Limited)
New Zealand (via Lloyd's Register Asia)
Poland (via Lloyd's Register (Polska) Sp zoo)
Spain (via Lloyd's Register EMEA)
United States of America (via Lloyd's Register North America, Inc.)

■ *Section 3* **Technical Committee**

3.1 LR maintains a Technical Committee, at present comprised of a maximum of 80 members, and additionally an Offshore Technical Committee with specific responsibility for LR's Rules for Offshore Units, at present comprised of a maximum of 80 members. Membership of the Technical Committees includes:

Ex officio members:

- Chairman and Chief Executive Officer of Lloyd's Register Group Limited
- Chairman of the Classification Committee of Lloyd's Register Group Limited

Members Nominated by:

- Technical Committee or Offshore Technical Committee
- Professional bodies representing technical disciplines relevant to the industry
- National and International trade associations with competence relevant to technical issues related to LR's business

3.2 In addition to the foregoing:

(a) Each National or Area Committee may appoint a representative to attend meetings of the Technical Committees.
(b) A maximum of five further representatives from National Administrations may be co-opted to serve on the Technical Committees. Representatives from National Administrations may also be elected as members of the Technical Committees as Nominated Members.
(c) Further persons may be co-opted to serve on the Technical Committees by the relevant Technical Committee.

3.3 All elections are subject to confirmation by the Board.

3.4 The function of the Technical Committees is to consider:

(a) any technical issues connected with LR's business;
(b) any proposed alterations in the existing Rules;
(c) any new Rules for classification;

Where changes to the Rules are necessitated by mandatory implementation of International Conventions and Codes, or Common Rules, Unified Requirements and Interpretations adopted by the International Association of Classification Societies, these may be implemented by LR without consideration by the relevant Technical Committee, although any such changes may be provided to the Technical Committees for information.

Where changes to the Rules are required by LR to enable existing technical requirements within the Rules to be recognised as Class Notations or Descriptive Notes, these may be implemented by LR without consideration by the relevant Technical Committee, although any such changes will be provided to the relevant Technical Committee for information

3.5 The term of office of the Chairman and of all members of each Technical Committee is five years. Members may be re-elected to serve an additional term of office with the approval of the Board. The term of office of the Chairman may be extended with the approval of the Board.

3.6 In the case of continuous non-attendance of a member, the relevant Technical Committee may withdraw membership.

3.7 Meetings of the Technical Committees are convened as often and at such times and places as is necessary, but there is to be at least one meeting in each year. Matters may also be considered by the Technical Committees by correspondence.

3.8 Any proposal involving any alteration in, or addition to the General Regulations, of Rules for Classification is subject to approval of the Board. All other proposals for additions to or alterations to the Rules for Classification other than the General Regulations, will following consideration and approval by the relevant Technical Committee either at a meeting of that Technical Committee or by correspondence, be recommended to the Board for adoption.

3.9 The Technical Committees are empowered to:

(a) appoint sub-Committees or panels; and
(b) co-opt to the Technical Committee, or to its sub-Committees or panels, representatives of any organisation or industry or private individuals for the purpose of considering any particular problem.

■ *Section 4*
Naval Ship Technical Committee

4.1 LR's Naval Ship Technical Committee is at present composed of a maximum of 50 members and includes:

Ex officio members:

- Chairman and Chief Executive Officer of Lloyd's Register Group Limited

Member nominated by:

- Naval Ship Technical Committee;
- The Royal Navy and the UK Ministry of Defence;
- UK Shipbuilders, Ship Repairers and Defence Industry;
- Overseas Navies, Governments and Governmental Agencies;
- Overseas Shipbuilders, Ship Repairers and Defence Industries;

4.2 All elections are subject to confirmation by the Board.

4.3 All members of the Naval Ship Technical Committee are to hold security clearance from their National Authority for the equivalent of NATO CONFIDENTIAL. All material is to be handled in accordance with NATO Regulations or, for non-NATO countries, an approved equivalent. No classified material shall be disclosed to any third party without the consent of the originator.

4.4 The term of office of the Naval Ship Technical Committee Chairman and of all members of the Naval Ship Technical Committee is five years. Members may be re-elected to serve an additional term of office with the approval of the Board. The term of the Chairman may be extended with the approval of the Board.

4.5 In the case of continuous non-attendance of a member, the Naval Ship Technical Committee may withdraw membership.

4.6 The function of the Naval Ship Technical Committee is to consider technical issues connected with Naval Ship matters and to approve proposals for new Naval Ship Rules, or amendments to existing Naval Ship Rules. Where appropriate, Naval Ship Technical Committee may also recognise alternative LR Rule requirements that have been approved by the other Lloyd's Register Technical Committee as adjunct to the Naval Ship Rules.

4.7 Meetings of the Naval Ship Technical Committee are convened as necessary but there will be at least one meeting per year. Urgent matters may be considered by the Naval Ship Technical Committee by correspondence.

4.8 Any proposal involving any alteration in, or addition to, the General Regulations of Rules for Classification of Naval Ships is subject to approval of the Board. All other proposals for additions to or alterations to the Rules for Classification of Naval Ships, other than the General Regulations, will following consideration and approval by the Naval Ship Technical Committee, either at a meeting of the Naval Ship Technical Committee or by correspondence, be recommended to the Board for adoption.

4.9 The Naval Ship Technical Committee is empowered to:

(a) appoint sub-Committees or panels; and
(b) co-opt to the Naval Ship Technical Committee, or to its sub-Committees or panels, representatives of any organisation or industry or private individuals for the purpose of considering any particular problem.

Section 5
Applicability of Classification Rules and Disclosure of Information

5.1 LR has the power to adopt, and publish as deemed necessary, Rules relating to classification and has (in relation thereto) provided the following:

(a) Except in the case of a special directive by the Board, no new Regulation or alteration to any existing Regulation relating to classification or to class notations is to be applied to existing ships.

(b) Except in the case of a special directive by the Board, or where changes necessitated by mandatory implementation of International Conventions, Codes or Unified Requirements adopted by the International Association of Classification Societies are concerned, no new Rule or alteration in any existing Rule is to be applied compulsorily after the date on which the contract between the ship builder and shipowner for construction of the ship has been signed, nor within six months of its adoption. The date of 'contract for construction' of a ship is the date on which the contract to build the ship is signed between the prospective shipowner and the ship builder. This date and the construction number (i.e. hull numbers) of all the vessels included in the contract are to be declared by the party applying for the assignment of class to a newbuilding. The date of 'contract for construction' of a series of sister ships, including specified optional ships for which the option is ultimately exercised, is the date on which the contract to build the series is signed between the prospective shipowner and the ship builder. In this section a 'series of sister ships' is a series of ships built to the same approved plans for classification purposes, under a single contract for construction. The optional ships will be considered part of the same series of sister ships if the option is exercised not later than 1 year after the contract to build the series was signed. If a contract for construction is later amended to include additional ships or additional options, the date of 'contract for construction' for such ships is the date on which the amendment to the contract is signed between the prospective shipowner and the ship builder. The amendment to the contract is to be considered as a 'new contract'. If a contract for construction is amended to change the ship type, the date of 'contract for construction' of this modified vessel, or vessels, is the date on which the revised contract or new contract is signed between the Owner, or Owners, and the shipbuilder. Where it is desired to use existing approved ship or machinery plans for a new contract, written application is to be made to LR. Sister ships may have minor design alterations provided that such alterations do not affect matters related to classification, or if the alterations are subject to classification requirements, these alterations are to comply with the classification requirements in effect on the date on which the alterations are contracted between the prospective owner and the ship builder or, in the absence of the alteration contract, comply with the classification requirements in effect on the date on which the alterations are submitted to LR for approval. Recognising the long time period that may occur between the initial design contract and the contract for construction for offshore units for fixed locations, the date determining effective classification requirements will be specially considered by LR in such cases.

(c) All reports of survey are to be made by surveyors authorised by members of the LR Group to survey and report (hereinafter referred to as 'the Surveyors') according to the form prescribed, and submitted for the consideration of the Classification Committee.

(d) Information contained in the reports of classification and statutory surveys will be made available to the relevant owner, National Administration, Port State Administration, P&I Club, hull underwriter and, if authorised in writing by that owner, to any other person or organisation.

(e) Notwithstanding the general duty of confidentiality owed by LR to its client in accordance with the LR Rules, LR clients hereby accept that, LR will participate in the IACS Early Warning System which requires each IACS member to provide its fellow IACS members and Associates with relevant technical information on serious hull structural and engineering systems failures, as defined in the IACS Early Warning System (but not including any drawings relating to the ship which may be the specific property of another party), to enable such useful information to be shared and utilised to facilitate the proper working of the IACS Early Warning System. LR will provide its client with written details of such information upon sending the same to IACS Members and Associates.

(f) Information relating to the status of classification and statutory surveys and suspensions/withdrawals of class together with any associated conditions of class will be made available as required by applicable legislation or court order.

(g) A Classification Executive consisting of senior members of LR's Classification Department staff shall carry out whatever duties that may be within the function of the Classification Committee that the Classification Committee assigns to it.

■ *Section 6* Ethics

6.1 No LR Group employee is permitted under any circumstances, to accept, directly or indirectly, from any person, firm or company, with whom the work of the employee brings the employee into contact, any present, bonus, entertainment or honorarium of any sort whatsoever which is of more than nominal value or which might be construed to exceed customary courtesy extended in accordance with accepted ethical business standards.

■ *Section 7* Non-Payment of Fees

7.1 LR has the power to withhold or, if already granted, to suspend or withdraw any ship from class (or to withhold any certificate or report in any other case), in the event of non-payment of any fee to any member of the LR Group.

■ *Section 8* Limits of Liability

8.1 When providing services LR does not assess compliance with any standard other than the applicable LR Rules, international conventions and other standards agreed in writing.

8.2 In providing services, information or advice, LR does not warrant the accuracy of any information or advice supplied. Except as set out herein, LR will not be liable for any loss, damage or expense sustained by any person and caused by any act, omission, error, negligence or strict liability of LR or caused by any inaccuracy in any information or advice given in any way by or on behalf of LR even if held to amount to a breach of warranty. Nevertheless, if the Client uses LR services or relies on any information or advice given by or on behalf of LR and as a result suffers loss, damage or expense that is proved to have been caused by any negligent act, omission or error of LR or any negligent inaccuracy in information or advice given by or on behalf of LR then LR will pay compensation to the client for its proved loss up to but not exceeding the amount of the fee (if any) charged for that particular service, information or advice.

8.3 LR will print on all certificates and reports the following notice: Lloyd's Register Group Limited, its affiliates and subsidiaries and their respective officers, employees or agents are, individually and collectively, referred to in this clause as ‘Lloyd's Register’. Lloyd's Register assumes no responsibility and shall not be liable to any person for any loss, damage or expense caused by reliance on the information or advice in this document or howsoever provided, unless that person has signed a contract with the relevant Lloyd's Register entity for the provision of this information or advice and in that case any responsibility or liability is exclusively on the terms and conditions set out in that contract.

8.4 Except in the circumstances of section *Pt 1, Ch 1, 8 Limits of Liability 8.2* above, LR will not be liable for any loss of profit, loss of contract, loss of use or any indirect or consequential loss, damage or expense sustained by any person caused by any act, omission or error or caused by any inaccuracy in any information or advice given in any way by or on behalf of LR even if held to amount to a breach of warranty.

8.5 Any dispute about LR services is subject to the exclusive jurisdiction of the English courts and will be governed by English law.

■ *Section 1* Conditions for classification

1.1 General

1.1.1 The *Rules and Regulations for the Classification of Special Service Craft*, (hereinafter referred to as the Rules for Special Service Craft), are applicable to those types of craft which are defined in *Pt 1, Ch 2, 2.1 Applicable craft types*. Where the word craft is used in the text of the Rules, it is to be taken as being applicable to yachts and other craft as stated herein unless specifically indicated otherwise.

1.1.2 The Rules are framed on the understanding:

(a) that the craft will at all times be properly loaded. They do not, unless stated or implied in the class notation, provide for special distributions or concentrations of loading associated with the operation of the craft. Lloyd's Register (hereinafter referred to as 'LR') may require additional strengthening to be fitted in any craft, which, in their opinion, would otherwise be subjected to severe stresses due to particular features in the design or operation, or where it is desired to make provision for exceptional loading conditions. In such cases particulars and details of the required loadings are to be submitted for consideration,

(b) that the craft will at all times be properly handled, with particular reference to the placing on board of persons and equipment and the reduction of speed in heavy weather,

(c) that compliance with the Rules does not relieve the designer of his responsibilities to his client for compliance with the specification and the requirements for the overall design and in service performance of the craft,

(d) that the craft will not be operated outside of the parameters specified in any operational envelope which may have been assigned, without the prior agreement of LR.

1.1.3 New craft built in accordance with the Rules, or in accordance with requirements equivalent thereto, will be assigned a class in the appropriate *Register Book* and will continue to be classed so long as they are found, upon examination at the prescribed surveys, to be maintained in accordance with the requirements of the Rules. Classification will be conditional upon compliance with LR's requirements for both hull and machinery.

1.1.4 The class notations of yachts will be recorded on the Class Direct website. The class notations of other craft will be recorded on the Class Direct website in the *Register of Ships*.

1.1.5 LR, in addition to requiring compliance with the Rules, will, in general, require to be satisfied that craft are suitable for the geographical or other limits or conditions of the service contemplated.

1.1.6 Loading conditions and any other preparations required to permit a craft with a notation specifying some service limitation to undertake a sea-going voyage, either from port of building to service area or from one service area to another, are to be in accordance with arrangements agreed by LR prior to the voyage.

1.1.7 Any damage, defect, breakdown or grounding, which could invalidate the conditions for which a class has been assigned, is to be reported to LR without delay. Any detention or arrest is also to be reported to LR without delay.

1.1.8 Where the provision of loading or stress monitoring equipment has been required by LR as the result of local, longitudinal or transverse strength calculations and the imposition of operating limitations, the necessary loading guidance information and operating instructions are to be incorporated in the relevant manuals supplied to the Master.

1.1.9 Where an onboard computer system having a longitudinal strength computation capability, which is required by the Rules, is provided on a new craft, or newly installed on an existing craft, then the system is to be certified in respect of longitudinal strength in accordance with LR's document entitled *Approval of Longitudinal Strength and Stability Calculation Programs*.

1.1.10 Where an onboard computer system having stability computation capability is provided on a new craft, then the system is to be certified in respect of stability aspects in accordance with LR's document entitled, *Approval of Longitudinal Strength and Stability Calculation Programs*. When provided, an onboard computer system having stability computation capability is to carry out the calculations and checks necessary to assess compliance with all the stability requirements applicable to the craft on which it is installed.

1.1.11 For craft, the arrangements and equipment of which are required to comply with the requirements of the:

- *International Convention on Load Lines;*
- *International Convention for the Safety of Life at Sea,*;
- *International Code of Safety for High Speed Craft (HSC Code)*;
- *International Convention for the Prevention of Pollution from ships.*
- International Convention on the Control of Harmful Anti-Fouling Systems on Ships;
- International Convention on Tonnage Measurement of Ships;
- Maritime Labour Convention.

The Classification Committee requires the applicable Convention and Code Certificates to be issued by authorities as follows:

- Cargo Ship Radio Certificates, Safety Management Certificates, International Ship Security Certificates and Maritime Labour Certificates, if required, must have been issued by a recognised organisation authorised by the National Administration with which the ship is registered.

- all other mandatory statutory certificates must have been issued by LR or by a National Administration or by an IACS Member when so authorised by the National Administration with which the ship is registered.

In the event of a National Administration withdrawing any ship's Convention Certificate (referred to in this Section), then the Classification Committee may suspend the ship's class. If a ship is removed from the National Administration's Registry for the non-compliance with the Conventions or Classification Requirements referred to herein, then the Classification Committee will suspend the ship's class. In the event of ISM Code certification being withdrawn from a ship or Operator, then the Classification Committee will suspend the ship's class.

1.1.12 In the case of dual classed craft, Convention certificates may be issued by the other classification society with which the craft is classed provided this is recognised in a formal Dual Class Agreement with LR and provided the other classification society is also authorised by the National Authority.

1.1.13 Yachts with a load line length of 24 m and above will be assigned a service type notation **Yacht** only after it has been demonstrated that the stability of the yacht complies with the stability requirements of the National Administration.

1.1.14 Yachts will be assigned a service type notation **Passenger Yacht** only after it has been demonstrated that the yacht is built in accordance with the applicable requirements of these Rules and complies with:

(a) *Pt 5 Main and Auxiliary Machinery* of the LR *Rules and Regulations for the Classification of Ships, July 2021* as applicable to passenger ships;
(b) *Pt 6 Control, Electrical, Refrigeration and Fire* of the LR *Rules and Regulations for the Classification of Ships, July 2021,* as applicable to passenger ships; and
(c) Construction requirements in accordance with Administration requirements for passenger yachts with due regard to the applicability of conventions given in *Pt 1, Ch 2, 1.1 General 1.1.11*, as determined in accordance with *The Red Ensign Group Yacht Code Part B* as amended or an alternative administration code deemed acceptable to LR.

1.2 Application

1.2.1 Except in the case of a special directive by the Committee, no new Regulation or alteration to any existing Regulation relating to character of classification or to class notations is to be applied to existing craft.

1.3 Interpretation of the Rules

1.3.1 The interpretation of the Rules is the sole responsibility, and at the sole discretion, of LR.

1.4 Scope of classification

1.4.1 Classification covers the structural design, watertight integrity and standard of construction of the hull and construction, installation and testing of the propulsion machinery, essential auxiliary machinery, essential piping and electrical systems to the extent indicated within these Rules.

1.4.2 Outfit, other than that covered by *Pt 1, Ch 2, 1.4 Scope of classification 1.4.1*, general finish, noise levels, vibration (other than shaft vibration where applicable), trim, design speed and stability, except as mentioned in *Pt 1, Ch 2, 1.1 General 1.1.11* and *Pt 1, Ch 2, 1.1 General 1.1.13* are outside the scope of classification.

1.4.3 Where a craft is so badly damaged that class has to be suspended, LR is prepared to assist the Owner with advice if requested.

1.4.4 The attention of Owners and Builders is drawn to statutory requirements which may be imposed by the relevant National Administration and which may not be within the scope of classification.

1.5 Client's responsibilities

1.5.1 The Client is to give LR's Surveyors every facility and necessary access to carry out their survey duties. The Client should familiarise himself with the relevant LR Rules and, where appropriate, arrange that all sub-contractors, suppliers of components, materials or equipment do the same.

1.5.2 The survey procedures undertaken by LR when providing services are on the basis of periodical visits involving both monitoring and direct survey, and LR's Surveyors will not be in continual attendance at LR's Client's premises. As construction and outfitting are continuous processes, the Builder has the overall responsibility to his client to ensure and document that the requirements of the Rules, approved drawings and any agreed amendments made by the attending LR Surveyors have been complied with.

■ *Section 2*
Scope of the Rules

2.1 Applicable craft types

2.1.1 The Rules are applicable to the following craft types constructed from steel, aluminium alloy, composite materials or combinations of these materials:

(a) High speed craft.
(b) Light displacement craft.
(c) Multi-hull craft.
(d) Yachts of overall length, L_{OA}, 24 metres or greater.
(e) Craft with draught to depth ratio less than or equal to 0,55.

2.1.2 The following craft types will be considered upon request on the basis of the Rules:

(a) Amphibious air cushion vehicles.
(b) Rigid inflatable boats.
(c) Hydrofoil craft.
(d) Foil assisted craft.
(e) Craft with a Rule length, L_R, less than 24 metres and draught to depth ratio greater than 0,55.

2.1.3 Existing yachts, regardless of length, are subject to the survey requirements defined in *Pt 1, Ch 4 Periodical Survey Regulations for Yachts*.

2.1.4 The Rules incorporate those requirements of the *International Convention for the Safety of Life at Sea, 1974* as amended (SOLAS 74) *Chapter X - Safety measures for high-speed craft* - Safety Measures for High Speed Craft (*International Code of Safety for High Speed Craft*) hereinafter referred to as the HSC code, as applicable to the classification of such craft.

2.1.5 At the discretion of LR craft types which are specifically covered by LR's *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships) or other LR Rules and Regulations for Classification may be considered for classification in accordance with these Rules and Regulations.

2.1.6 Where any aspect of the design or construction is not covered by the Rules, the relevant requirements of the Rules for Ships or the *Rules and Regulations for the Classification of Naval Ships* (hereinafter referred to as the Rules for Naval Ships) will be applied as considered necessary.

2.2 Definitions

2.2.1 For the purpose of the Rules, the definitions given in *Pt 1, Ch 2, 2.2 Definitions 2.2.2* will apply.

2.2.2 **Air Cushion Vehicle.** An Air Cushion Vehicle (ACV) is a craft such that the whole or a significant part of its weight can be supported, whether at rest or in motion, by a continuously generated cushion of air dependent for its effectiveness on the proximity of the surface over which the craft operates.

2.2.3 **Assisted craft.** An assisted craft is any craft operating on a route where it has been demonstrated to the satisfaction of the Administrations concerned that there is a high probability that in the event of an evacuation at any point of the route, all passengers and crew can be rescued safely within the time specified in the HSC Code.

2.2.4 **Catamaran.** A catamaran is a craft with twin-hulls linked by a bridging structure.

2.2.5 **Composite materials.** Composite materials are those construction materials consisting principally of fibre reinforced plastics.

2.2.6 **Design waterline** is the waterline corresponding to the maximum operational weight of the craft with no lift or propulsion machinery active.

2.2.7 **Foil assisted craft.** A foil assisted craft is a craft designed such that a significant part of its weight, whilst in motion, is supported by hydrodynamic lift generated by foils.

2.2.8 **High speed craft.** A high speed craft is a craft capable of maximum speed, V, *see Pt 1, Ch 2, 2.2 Definitions 2.2.13* not less than

$$V = 7{,}19\ \nabla^{1/6} \text{ knots}$$

where

∇ = moulded displacement, in m^3, of the craft corresponding to the design waterline.

2.2.9 **Hydrofoil craft.** A hydrofoil craft is a craft which is supported above the water surface in non-displacement mode by hydrodynamic forces generated by foils.

2.2.10 **Laid-up notation.** A craft not under repair or not actively employed may be assigned the **Laid-up** notation in order to maintain the ship in class subject to agreement by the Classification Committee. A general examination of the hull and machinery is to be carried out in lieu of the Annual Survey/Intermediate Survey. A general examination of the hull and machinery and an Underwater Examination (UWE) is to be carried out in lieu of the Special Survey, *see Pt 1, Ch 3, 2.1 General 2.1.3*, *Pt 1, Ch 3, 5.1 General 5.1.4* and *Pt 1, Ch 3, 7.1 Annual, Intermediate and Bottom Surveys 7.1.3*.

2.2.11 **Light displacement craft.** A light displacement craft is a craft with a displacement not exceeding:

$$\Delta = 0{,}04\left(L_{R}B\right)^{1,5} \text{ tonnes}$$

where

= L_R and B are defined in *Pt 3, Ch 1 General Regulations*.

2.2.12 **Low wash catamaran**. A low wash catamaran is a particular type of catamaran that has low wash wake characteristics for a specified operating envelope. These vessels are typically of a displacement or semi-displacement form.

2.2.13 **Maximum speed.** Maximum speed is the speed, in knots, achieved at the maximum continuous power for which the craft is certified at maximum operational weight and in smooth water.

2.2.14 **Mono-hull craft.** A mono-hull craft is a craft whose single hull may be of displacement form or of a semi-planing or planing form subject to some support by hydrodynamic lift.

2.2.15 **Multi-hull craft.** A multi-hull craft is a craft with two or more hulls linked by a bridging structure which may be of displacement form or of a semi-planing or planing form subject to some support by hydrodynamic lift.

2.2.16 **Operational speed.** Operational speed is the speed, in knots, corresponding to that permitted by the operational envelope. For High Speed Craft it is not more than 90 per cent of the maximum speed.

2.2.17 **Operational envelope.** The operational envelope defines the craft's structural capability in terms of operational speeds, wave heights and displacements.

2.2.18 **Passenger.** A passenger is every person other than:

(a) The Master and the members of the crew or other persons employed or engaged in any capacity on board a craft on the business of that craft, and
(b) a child under one year of age.

2.2.19 **Passenger craft.** A passenger craft is a craft which carries more than twelve passengers.

2.2.20 **Passenger yacht.** A passenger yacht is a craft in commercial or non-commercial use for sport or pleasure and may be propelled mechanically, by sail, or by a combination of both.*See also Pt 1, Ch 2, 1.1 General 1.1.14*.

2.2.21 **Patrol craft.** A patrol craft is a craft which may be operated by the harbour, police, customs, military authorities, search and rescue or similar organisations.

2.2.22 **Pilot launch.** A pilot launch is a craft designed to come alongside ships whilst at sea to embark or disembark pilots.

2.2.23 **Place of refuge.** A place of refuge is any naturally or artificially sheltered area which may be used as a shelter by a craft under conditions likely to endanger its safety.

2.2.24 **Range to refuge.** Range to refuge is the maximum allowable distance in nautical miles, measured along the shortest safe navigational track from any point on the intended voyage route of the craft to the nearest accessible harbour or place of refuge.

2.2.25 **Reasonable weather.** Reasonable weather is defined as wind strengths of force six or less on the Beaufort scale, associated with:

(a) Sea states within the operational envelope which are sufficiently moderate to ensure that green water is taken on board at infrequent intervals only or not at all.
(b) Motions such as do not impair the efficient operation of the craft and do not significantly reduce passenger comfort or safety or impose any undue loads on any cargo carried.

2.2.26 **Rigid Inflatable Boat.** A Rigid Inflatable Boat (RIB) is a craft combining a rigid hull enclosed by a watertight self-draining deck situated above the deepest operational load waterline and provided with a gas, air or foam-filled flotation collar/fender at the edge of the deck above the hull to improve the stability and to augment the reserve of buoyancy and sea-keeping ability of the rigid hull.

2.2.27 **Service craft.** Service craft is any craft within the scope of the Rules other than a yacht or an amphibious air cushion vehicle.

2.2.28 **Small Waterplane Area Twin Hull Ship.** A Small Waterplane Area Twin Hull Ship (SWATH) is a twin-hulled craft characterised by bulbous lower hulls (torpedoes) and relatively narrow struts connecting them to the haunches and deck structure.

2.2.29 **ShipRight notation.** A notation indicating that one or more of LR's ShipRight procedures have been satisfactorily followed. Class notations or descriptive notes will be assigned according to whether the ShipRight procedures are applied on a mandatory or voluntary basis.

2.2.30 **Surface Effect Ship.** A Surface Effect Ship (SES) is an air-cushion vehicle whose cushion is totally or partially retained by permanently immersed rigid structures.

2.2.31 **Unassisted craft.** An unassisted craft is any craft other than an assisted craft, with machinery and safety systems arranged such that, in the event of damage disabling any essential machinery and safety systems in one compartment, the craft retains the capability to navigate safely as defined in the HSC Code.

2.2.32 **Wave piercing catamaran.** A wave piercing catamaran is a particular type of catamaran which is designed such that the hulls provide positive freeboard when at rest in still water but which are expected to become partially submerged when advancing in waves.

2.2.33 **Yacht.** A yacht is a craft in commercial or non-commercial use for sport or pleasure and may be propelled mechanically, by sail, or by a combination of both.

2.2.34 **Yacht support vessel**. A yacht support vessel is designed and built to support a yacht. It provides equipment and facilities that would be too large or cumbersome on the yacht. It does not cover workboats that are occasionally hired to provide specialist services to yachts.

2.2.35 **Wind Farm Service Vessel.** A Wind Farm Service Vessel is a craft designed for duties specific to the maintenance and support of offshore wind farms.

2.2.36 **Workboat.** A workboat is a general purpose service craft which may be adapted for duties such as line handling, towing, tender, survey, fishing, oil spill recovery, or diving support.

■ *Section 3* Character of classification and class notations

3.1 General

3.1.1 This Section details the character symbols and notations which comprise the class assigned to special service craft.

3.1.2 LR may require an operational envelope as defined in *Pt 1, Ch 2, 2.2 Definitions 2.2.17* to be assigned to craft built and classed in accordance with the Rules; this will be dependent upon the scantlings, arrangements and the operating mode of the craft as specified by the builder, *see Pt 5, Ch 1 General*. When an operational envelope is assigned it will form an appendix to the Classification Certificate and is to be clearly displayed in the wheelhouse. The operational envelope is also to be included in the operational manual of the craft. A reference to the operational envelope will be made in the Classification Certificate.

3.1.3 Craft built and classed in accordance with the Rules for restricted service will have their geographical limits included in the Classification Certificate.

3.2 Character symbols

3.2.1 All craft, when classed, will be assigned a character of classification comprising one or more character symbols as applicable, e.g. ✠ **100A1 SSC**.

3.2.2 A full list of character symbols for which craft may be eligible is as follows:

(a) ✠ This distinguishing mark will be assigned, at the time of classing, to new craft constructed under LR’s Special Survey, in compliance with the Rules, and to the satisfaction of the Committee.

(b) $\overline{✠}$ This distinguishing mark will be assigned, at the time of classing, to new craft constructed under LR’s Special Survey in accordance with plans approved by another IACS member society.

(c) $\dot{✠}$ This distinguishing mark will be assigned to new craft built under supervision of another IACS member society and later assigned class with LR. For such craft the class notations will be reviewed separately and equivalent notations will be assigned.

(d) **100** This character figure will be assigned to all craft considered suitable for sea-going service except those in Service Group **G1**, **Zone 1**, **Zone 2** and **Zone 3**, *see Pt 1, Ch 2, 3.5 Service area restriction notations 3.5.5*.

(e) **A** This character letter will be assigned to all craft which have been built or accepted into class in accordance with LR's Rules and Regulations, and which are maintained in good and efficient condition.

(f) **1** This character figure will be assigned to:

- (i) Craft having on board, in good and efficient condition, anchoring and/or mooring equipment in accordance with the Rules.
- (ii) Craft classed for a specific service, having on board, in good and efficient condition, anchoring and/or mooring equipment approved by the Committee as suitable and sufficient for the particular service.

(g) **N** This character letter will be assigned to craft on which the Committee has agreed that anchoring and mooring equipment need not be fitted in view of their particular service.

(h) **T** This character letter will be assigned to ships which are intended to perform their primary designed service function only while they are anchored, moored, towed or linked, and which have, in good and efficient condition, adequately attached anchoring, mooring, towing or linking equipment which has been approved by the Committee as suitable and sufficient for the intended service.

(i) **SSC** These character letters will be assigned to craft indicating that the craft has been constructed or accepted into class on the basis of the Rules.

3.2.3 For classification purposes the character figure **1** or the character letter **N** is to be assigned.

3.2.4 In cases where the anchoring and/or mooring equipment is found to be seriously deficient in quality or quantity, the class of the craft will be liable to be withheld.

3.3 Class notations (hull)

3.3.1 When considered necessary by the Committee, or when requested by an Owner and agreed by the Committee, a class notation will be appended to the character of classification assigned to the craft. The class notation will consist of one of, or a combination of:

(a) a high speed craft notation;
(b) a light displacement craft notation;
(c) a service area restriction notation;
(d) a service type notation;
(e) a craft type notation;
(f) other hull notations;

e.g.

✠ **100A1**	SSC Passenger (A) Catamaran
	HSC G3 `service area'
✠ **100A1**	SSC Yacht Catamaran
	LDC G5

3.3.2 A list of class notations (hull) for which a craft may be eligible is given in *Pt 1, Ch 2, 3.4 High speed craft and light displacement craft notations*.

3.4 High speed craft and light displacement craft notations

3.4.1 **HSC - High speed craft notation.** This class notation will be assigned to high speed craft as defined in *Pt 1, Ch 2, 2.2 Definitions 2.2.8*.

3.4.2 **LDC - Light displacement craft notation.** This class notation will be assigned to light displacement craft as defined in *Pt 1, Ch 2, 2.2 Definitions 2.2.11*.

3.5 Service area restriction notations

3.5.1 All craft classed under the Rules will be assigned a service area restriction notation **G** followed by a number e.g **G1**, or **Zone** followed by a number, e.g. **Zone 1**. Craft classed under the Rules for service groups **G1** to **G5** and **Zone 1** to **Zone 3** are not suitable for unrestricted service except as noted in the service area restriction notation, *see Pt 1, Ch 2, 3.5 Service area restriction notations 3.5.5*.

3.5.2 Service area restriction notations, given in *Pt 1, Ch 2, 3.5 Service area restriction notations 3.5.5*, are expressed in terms of range to refuge in nautical miles as defined in *Pt 1, Ch 2, 2.2 Definitions 2.2.23*.

3.5.3 Where craft are required to satisfy limitations in respect of the maximum duration of time to a place of refuge from any point during the voyage, this time is to be determined by dividing the range to refuge by the permitted operational speed of the craft (when fully laden) in the prevailing conditions as imposed by the operational envelope.

3.5.4 For craft that are designed in accordance with an operational envelope:

- these craft are to be operated at reduced speeds and are to seek calmer waters or refuge when the weather conditions deteriorate or are predicted to deteriorate in order that the craft is not exposed to a significant wave height and speed combination which exceeds the limits of the operational envelope.

For craft that are not assigned an operational envelope:

- these craft are to be operated at reduced speeds and are to seek calmer waters or refuge when the weather conditions deteriorate or are predicted to deteriorate.

All craft are to be aware of the weather forecast for the proposed and current areas of operation and area of refuge.

3.5.5 The following inland, coastal and seagoing service area restriction notations describe the service area restriction for which a craft has been approved and constructed.

(a) **Zone 3** covers craft intended for operation in inland waters where the maximum recorded significant wave height based on long-term significant wave height statistics excluding the highest five per cent of the recorded significant wave heights does not exceed 0,5 m. The geographical limits of the intended service are to be identified by the Builder and agreed with LR. Craft in this group are not considered as 'seagoing' and are not eligible for the assignment of the character figure **100**.
(b) **Zone 2** covers craft intended for operation in inland waters and estuaries where the maximum recorded significant wave height based on long-term significant wave height statistics excluding the highest five per cent of the recorded significant wave heights does not exceed 1,0 m. The geographical limits of the intended service are to be identified by the Builder and agreed with LR. Craft in this group are not considered as 'seagoing' and are not eligible for the assignment of the character figure **100**.
(c) **Zone 1** covers craft intended for operation in inland waters and estuaries where the maximum recorded significant wave height based on long-term significant wave height statistics excluding the highest five per cent of the recorded significant wave heights does not exceed 1,6 m. The geographical limits of the intended service are to be identified by the Builder and agreed with LR. Craft in this group are not considered as 'seagoing' and are not eligible for the assignment of the character figure **100**.
(d) **G1 Service Group 1** covers craft intended for service in sheltered waters adjacent to sandbanks, estuaries, reefs, breakwaters or other coastal features and in similarly sheltered waters between islands in reasonable weather where the range to refuge is, in general, five nautical miles or less. The geographical limits of the intended service are to be identified by the Builder and agreed with LR. Craft in this group are not eligible for the assignment of the character figure **100**.
(e) **G2 Service Group 2** covers craft intended for service in reasonable weather, in waters where the range to refuge is 20 nautical miles or less. This group will usually cover craft intended for service in coastal waters, for which geographical limits are to be identified by the Builder and agreed with LR.
(f) **G2A Service Group 2A** covers craft intended for service in reasonable weather in waters where the range to refuge is 60 nautical miles or less. The geographical limits of the intended service are to be reported to LR. Craft in this group are eligible for assignment of the service type notation **SRY**.
(g) **G3 Service Group 3** covers craft intended for service in waters where the range to refuge is 150 nautical miles or less. The geographical limits of the intended service are to be reported to LR.
(h) **G4 Service Group 4** covers craft intended for service in waters where the range to refuge is 250 nautical miles or less. The geographical limits of the intended service are to be reported to LR.
(i) **G5 Service Group 5** covers craft intended for service in waters where the range to refuge is 350 nautical miles or less. The geographical limits of the intended service are to be reported to LR.
(j) **G6 Service Group 6** covers yachts and steel patrol craft having unrestricted service.

Non-seagoing craft are craft that are not eligible for the character figure **100**. Seagoing craft are craft eligible for the character figure **100**.

The above zone definitions, i.e. **Zone 1**, **Zone 2** and **Zone 3**, are considered to be consistent with the EC resolution ECE/TRANS/SC.3/172/Rev.1 zone definitions.

3.5.6 Consideration may be given to requests for an increase in the permissible range to refuge subject to:

(a) The specific geographic limits and the period over which the extended service is to be operated being defined.
(b) Satisfactory statistical data in respect of wave height being provided to demonstrate that the craft will be suitable for the extended service.
(c) Equipment consistent with that required for the extended service being provided onboard during the period of operation.
(d) Any maximum duration of voyage limitations imposed by *Pt 1, Ch 2, 3.5 Service area restriction notations 3.5.3* not being exceeded during the extended service.

3.6 Service type notations

3.6.1 The service type notation will be recorded in the appropriate *Register Book* indicating the primary purpose for which the craft has been designed and constructed.

3.6.2 A list of service type notations for which craft may be eligible is given below:

Cargo (A)	This notation will be assigned to cargo craft other than Cargo (B) craft.
Cargo (B)	This notation will be assigned to unassisted high speed cargo craft of 500 gross tons and over which do not proceed in the course of their voyage more than eight hours at operational speed from a place of refuge when fully laden. These craft correspond to `Cargo Craft' as defined in the HSC Code.
Passenger	This notation will be assigned to passenger craft other than **Passenger (A)** or **Passenger (B)** craft.
Passenger (A)	This notation will be assigned to assisted high speed craft carrying not more than 450 passengers on board and which do not proceed in the course of their voyage more than four hours at operational speed from a place of refuge when fully laden. These craft correspond to `Category A Craft' as defined in the HSC Code.
Passenger (B)	This notation will be assigned to unassisted high speed craft which may carry more than 450 passengers on board and which do not proceed in the course of their voyage more than four hours at operational speed from a place of refuge when fully laden. These craft correspond to `Category B Craft' as defined in the HSC Code.
Passenger Yacht	This notation will be assigned on request to yachts which are built in accordance with the applicable requirements of these Rules and requirements set out in *Pt 1, Ch 2, 1.1 General 1.1.14*.
Patrol	This notation will be assigned to patrol craft complying with the relevant requirements of the Rules.
Pilot	This notation will be assigned to pilot launches complying with the relevant requirements of the Rules.
Yacht	This notation will be assigned to all yachts
Yacht support vessel	This notation will be assigned to vessels that are, by design, associated with yachts and are intended to provide equipment or facilities.
Wind Farm Service Vessel	This notation will be assigned to Wind Farm Service Vessels that comply with the relevant requirements for workboats and which take into account specific Wind Farm Service applications that they may be required to undertake, *see* LR's *Guidance Notes for the Classification of Wind Farm Service Vessels.*
Workboat	This notation will be assigned to workboats complying with the relevant requirements of the Rules.

3.7 Craft type notations

3.7.1 The craft type notation will be recorded in the appropriate *Register Book* indicating the type of hull form and mode of operation for which the craft has been designed and constructed.

3.7.2 A list of craft type notations for which craft may be eligible is given below:

ACV	This notation will be assigned to amphibious air cushion vehicles built in accordance with the *Rules for the Classification of Air Cushion Vehicles, July 2021* (hereinafter referred to as Rules for ACVs) and the SSC Rules where referenced.
Catamaran	This notation will be assigned to all catamarans including low wash and wave piercing catamarans.
Hydrofoil	This notation will be assigned to hydrofoil craft.
Mono	This notation will be assigned to mono-hull craft other than amphibious air cushion vehicles, hydrofoils and rigid inflatable boats.
Multi	This notation will be assigned to multi-hull craft other than catamarans, swaths and surface effect ships.
RIB	This notation will be assigned to rigid inflatable boats.
SES	This notation will be assigned to surface effect ships.
Swath	This notation will be assigned to small waterplane area twin hull ships.

3.7.3 Where craft indicated in *Pt 1, Ch 2, 3.7 Craft type notations 3.7.2* are foil assisted the letters (FA) may be appended to the Craft Type Notation.

3.8 Other hull notations

3.8.1 **Ice Class.** A class notation for navigation in first-year ice conditions will be specially considered.

3.8.2 ***IWS.** This notation (In-Water Survey) may be assigned to a craft where the applicable requirements of LR's Rules and Regulations are complied with. (*See Pt 1, Ch 3, 4.3 In-Water Surveys* and *Pt 1, Ch 4, 3.3 In-Water Surveys*, *see also Pt 3, Ch 3, 2.37 In-water Survey requirements*).

3.8.3 **Special features notation.** A notation indicating that the craft incorporates special features which significantly affect the design, e.g. movable decks.

3.8.4 **Helicopter Landing Area.** Assigned where a helicopter landing area is provided in compliance with *Pt 6, Ch 5, 6 Helicopter landing areas* (Steel), or *Pt 7, Ch 5, 6 Helicopter landing areas* (Aluminium), or *Pt 8, Ch 5, 5 Helicopter landing areas* (Composites).

3.8.5 **LI.** This notation will be assigned where an approved loading instrument has been installed as a classification requirement.

3.8.6 **SRY**. This notation will be assigned to Short-Range Yachts with service area restriction G2A and designed and built in accordance with the *Red Ensign Group Yacht Code Part A* requirements for Short-Range Yachts or an alternative National Code acceptable to LR.

3.8.7 **ShipRight ACS (B).** The ShipRight Anti-Corrosion System notation **ShipRight ACS (B)** will be assigned when protective coating system of water ballast tanks has been applied in accordance with the ShipRight Procedure *Anti-Corrosion System Notation*.

3.8.8 **LA**. This mandatory notation is assigned where one or more lifting appliances are considered to be an essential feature of the vessel, e.g. cranes on crane barges, lifting arrangements for diving on diving support vessels.

3.8.9 **L̇A**. This mandatory notation is assigned where one or more lifting appliances are considered to be an essential feature of the vessel and have been classed by a recognised classification society other than LR and later transferred into class with LR. In such cases, a new Register of Ship’s Lifting Appliances & Cargo Handling Gear (LA.1) will be issued in accordance with LR’s *Code for Lifting Appliances in a Marine Environment, July 2021*.

3.8.10 **RIGGING**. The **RIGGING** notation will be assigned where a new craft is fitted with a rig used for propulsion by wind force which is in accordance with the Rules. *SeePt 3, Ch 7 Wind propulsion systems*.

3.8.11 **RIGGING***. Upon request, the **RIGGING*** notation will be assigned where an existing craft is fitted with a rig used for propulsion by wind force which is in accordance with the Rules. *See Pt 3, Ch 7 Wind propulsion systems*

3.9 Class notations (machinery)

3.9.1 The following class notations are associated with machinery construction and arrangements, and may be assigned as considered appropriate by the Committee:

✠ LMC This notation will be assigned when the propelling and essential auxiliary machinery has been constructed, installed and tested under LR's Special Survey and in accordance with LR's Rules and Regulations.

$\overline{✠}$ LMC This notation will be assigned when the propelling and essential auxiliary machinery has been constructed under the survey of a recognised authority in accordance with the Rules and Regulations equivalent to those of LR. In addition, the whole of the machinery will be required to have been installed and tested under LR's Special Survey in accordance with LR's Rules and Regulations.

[✠] LMC This notation will be assigned when the propelling arrangements, steering systems, pressure vessels and the electrical equipment for essential systems have been constructed, installed and tested under LR's Special Survey and are in accordance with LR's Rules and Regulations. Other items of machinery for propulsion and electrical power generation including propulsion gearing arrangements and other auxiliary machinery for essential services that are in compliance with LR Rules and supplied with the manufacturer's certificate will be acceptable under this notation. The system arrangements of propelling and essential auxiliary machinery are required to be appraised by LR, and found to be acceptable to LR. This notation is assigned subject to the conditions in *Pt 1, Ch 2, 3.10 Application notes 3.10.2* being complied with.

LMC This notation (without ✠) will be assigned when the propelling and essential auxiliary machinery has neither been constructed nor installed under LR's Special Survey but the existing machinery, its installation and arrangement, has been tested and found to be acceptable to LR. This notation is assigned to existing craft in service accepted or transferring into LR class.

MCH This notation will be assigned when the propelling and essential auxiliary machinery has been installed and tested under LR's survey requirements and found to be acceptable to LR. Items of machinery and equipment for propelling and auxiliary machinery for essential services supplied with the manufacturer's certificate will be acceptable under this class notation. The system arrangements of propelling and essential auxiliary machinery are required to be appraised by LR, and found to be acceptable to LR. This notation is assigned subject to the conditions in *Pt 1, Ch 2, 3.10 Application notes 3.10.3* being complied with.

3.9.2 The following class notations are associated with the machinery control and automation, and may be assigned as considered appropriate by the Classification Committee:

UMS This notation may be assigned when the arrangements are such that the unit can be operated with the machinery spaces unattended. It denotes that the control engineering equipment has been arranged, installed and tested in accordance with LR's Rules, or that it is equivalent thereto.

CCS This notation may be assigned when the arrangements are such that the machinery may be operated with continuous supervision from a centralised control station. It denotes that the control engineering equipment has been arranged, installed and tested in accordance with LR's Rules, or is equivalent thereto.

3.9.3 The following class notation is associated with vessels capable of being operated unmanned, and may be assigned as considered appropriate by the Classification Committee:

Unmanned Assigned when a vessel is designed and constructed such that it may be operated unmanned, i.e. without crew, passengers or other persons on board.

3.9.4 Machinery class notations will not be assigned to craft the hulls of which are not classed or intended to be classed with LR.

3.9.5 The notation ✠ **LMC**, $\overline{\maltese}$ **LMC**, [✠] **LMC**, **LMC** (without ✠) and **MCH** will in general not be assigned to non-propelled craft, but individual cases will be considered on their merits.

3.9.6 The following class notations are associated with hybrid electrical power systems and may be assigned as considered appropriate by the Classification Committee:

Hybrid Power Assigned to ships with an electrical power system utilising a combination of two or more different types of power source or utilising stored electrical energy to satisfy the ship's main power demand. The system and its component parts are in accordance with the existing applicable requirements of the Rules and the requirements of *Pt 16, Ch 2, 23 Hybrid electrical power systems*.

Hybrid Power (+) Assigned to ships meeting the requirements for **Hybrid Power** and the additional optional requirements for **Hybrid Power (+)** specified within *Pt 16, Ch 2, 23 Hybrid electrical power systems*. The additional optional requirements aim to provide for enhanced performance of the electrical power system achieved through the consideration of system simulation, system integration and the dependability of the hybrid electrical power system during normal or reasonably foreseeable abnormal operation.

3.10 Application notes

3.10.1 Propelling and essential auxiliary machinery includes machinery, equipment and systems installed for the craft/yacht to be under conditions as encountered in the defined sea area and that are necessary for the following:

(a) Maintaining the watertight and weathertight integrity of the hull and spaces within the hull.
(b) The safety of the craft/yacht, machinery and personnel on board.
(c) The functioning and dependability of propulsion, steering and electrical systems.
(d) The operation and functioning of control engineering systems for the monitoring and safety of propulsion, steering and electrical power systems.
(e) The operation and functioning of emergency machinery and equipment.

3.10.2 **Manufacturer's certificate** for assignment of the [✠] **LMC** notation. Acceptance of the manufacturer's certificate for items of machinery for propulsion (including propulsion gearing with single input/output arrangements) and for electrical power generation and for other auxiliary machinery for essential services is subject to the following:

(a) For a craft: The craft is intended for the carriage of cargo (not passengers), is less than 500 gross tonnage or is of 500 gross tonnage or greater and is not required to comply with international conventions applicable to a craft with unrestricted service.
(b) For a yacht with:
   (i) A gross tonnage of less than 500, and is not required to comply with international conventions.
   (ii) A gross tonnage of 500 or more and is not required to comply with international conventions applicable to a yacht with unrestricted service.
   (iii) A gross tonnage of 500 or more and its acceptance of manufacturer’s certificate as described above are specifically agreed by the administration of the country in which the yacht is registered.
(c) Propulsion power is provided by oil engines or gas turbines which have been type approved to LR requirements for marine application.
(d) Electrical power is provided by generators driven by oil engines or gas turbines which have been type approved to LR requirements for marine application.
(e) The design and manufacturing standards for all machinery and associated systems are the applicable LR Rules.
(f) The machinery and equipment is manufactured under a recognised quality control system.
(g) Propellers, propulsion shafting and multiple input/output gearboxes are not included within the scope of propulsion arrangements for acceptance of a manufacturer's certificate.

3.10.3 **Manufacturer's certificate** for assignment of the **MCH** notation. Acceptance of the manufacturer's certificate for propelling and essential auxiliary machinery is subject to the following:

(a) For a craft: The craft is intended for the carriage of cargo (not passengers), is less than 500 gross tonnage or is of 500 gross tonnage or greater and is not required to comply with international conventions applicable to a craft with unrestricted service.
(b) For a yacht: The yacht is less than 500 gross tonnage or is of 500 gross tonnage or more and is not required to comply with international conventions applicable to a yacht with unrestricted service.
(c) Propulsion power is provided by oil engines or gas turbines which have been type approved to LR requirements for marine application.
(d) Electrical power is provided by generators driven by oil engines or gas turbines which have been type approved to LR requirements for marine application.
(e) The power of any engine or gas turbine is less than 2,250 kW and the cylinder bore of any diesel engine is not greater than 300 mm.
(f) The design and manufacturing standards for machinery and associated systems are the applicable LR Rules or other marine standards acceptable to LR.
(g) The machinery and equipment is manufactured under a recognised quality control system.

3.11 Class notations (Environmental Protection)

3.11.1 The following class notations are associated with the design and operation of a Special Service Craft and may be assigned as considered appropriate by the Classification Committee, on application from the Owners:

ABN( )	This notation will be assigned where a vessel has had its airborne noise measured and certified in accordance with LR’s *ShipRight Additional Design and Construction Procedure for the determination of airborne noise emissions from marine vessels*, and the sound power and sound pressure are found to be less than the assessment criterial limits it contains. The parentheses are to contain the characters associated with the most stringent assessment criteria limits that the airborne noise of the vessel satisfies.
ECO	This notation may be assigned when the design and operation of a Special Service Craft are in accordance with the relevant requirements in *Pt 7, Ch 11 Arrangements and Equipment for Environmental Protection (ECO Class Notation)* of the Rules for Ships.
ECO(TOC)	This notation will be assigned when the environmental protection arrangements are in accordance with the requirements of another recognised classification society and are essentially equivalent to Rule requirements and the craft is operated in accordance with the relevant requirements of the Rules.

UWN-M	This notation will be assigned where a vessel has had its underwater radiated noise measured and certified in accordance with LR's *ShipRight Procedure Additional Design and Construction Procedure for the Determination of a Vessel's Underwater Radiated Noise.*
UWN-L ( )	This notation will be assigned where a vessel has had its underwater noise signature measured and certified in accordance with LR's *ShipRight Procedure Additional Design and Construction Procedure for the Determination of a Vessel's Underwater Radiated Noise* and the profile of the underwater radiated noise curve(s) are found to be less than the limits contained in the ShipRight Procedure. The parentheses are to contain the limit set in accordance with the ShipRight Procedure and listed therein.

3.12 Descriptive notes

3.12.1 In addition to any class notations, an appropriate descriptive note may be entered in column 6 of the appropriate *Register Book* indicating the type of craft in greater detail than is contained in the class notation, and/or providing additional information about the craft's design and construction. This descriptive note is not a LR classification notation and is provided solely for the information of users of the *Register Book*.

3.12.2 Screwshaft Condition Monitoring.

SCM	Screwshaft Condition Monitoring. This descriptive note will be assigned where an Owner adopts the requirements for monitoring of the screwshaft. The descriptive note will indicate that equipment and procedures are in place to determine the physical and operational condition of that equipment.

3.12.3 **ThCM** Thruster Condition Monitoring

This ShipRight descriptive note will be assigned where an Owner adopts the requirements for monitoring of selected Thrusters and/or Podded Propulsors. The descriptive note will indicate that equipment and procedures are in place to determine the physical and operational condition of that equipment. Further information is provided in the LR document *ShipRight Procedure Machinery Planned Maintenance and Condition Monitoring*. Note: Not applicable where a single thruster, or podded propulsor, is solely responsible for the propulsion and/or steering of the vessel.

3.12.4 **STV**. Where a sailing vessel is used for the offshore training of cadets or trainee seamen, a sailing training vessel **STV** descriptive note may be entered in column 6 of the *Register Book*.

3.12.5 **ESW**. Where a low wash catamaran is capable of demonstrating low wash wake characteristics, an environmentally sensitive wake **ESW** descriptive note may be entered in column 6 of the *Register book*. The descriptive note will be assigned where specified wave wake requirements of a local authority are complied with. The descriptive note is to be appended in brackets with the name of the local authority and/or the specified service route, e.g. **ESW(Port of London Authority)**.

3.12.6 **IHM**. This ShipRight descriptive note (Inventory of Hazardous Materials) will be assigned when the requirements in accordance with the relevant ShipRight procedures have been complied with.

3.12.7 **HCD1()** This ShipRight descriptive note (Human-Centred Design Level 1) will be assigned when the development and operation of specified ship system(s) has been carried out in accordance with the process for 'Level 1 – Reactive' detailed in the *ShipRight Procedure for Human-centred Design*. The names of the systems which meet the requirements will be listed as a suffix to the character, e.g. **HCD1**(mooring area, ECDIS).

■ *Section 4*
Surveys - General

4.1 Statutory surveys

4.1.1 The Committee will act, when authorised on behalf of Governments, in respect of National and International statutory safety and other requirements.

4.1.2 The Committee will also act, when authorised, in respect of National safety and other requirements relating to craft used for offshore mineral exploration and exploitation.

4.2 New construction surveys

4.2.1 When it is intended to build a craft for classification with LR, constructional plans and all particulars relevant to the hull, equipment and machinery, as detailed in the Rules, are to be submitted for the approval of the Committee before the work is commenced. Proposals for any subsequent modifications or additions to the scantlings, arrangements or equipment shown on the approved plans are also to be submitted in writing and on plans for approval.

4.2.2 Where the proposed construction of any part of the hull or machinery is of novel design, or involves the use of unusual material, or where experience, in the opinion of the Committee, has not sufficiently justified the principle or mode of application involved, special tests or examinations before and during service may be required. In such cases a suitable notation may be entered in the appropriate *Register Book*.

4.2.3 The materials used in the construction of hulls and machinery intended for classification are to be of good quality and free from defects and are to comply with the requirements of the Rules.

4.2.4 The Surveyor is to be satisfied that the capability, organisation and facilities of the Builder are such that acceptable standards can be obtained both for the construction of the craft and the installation of machinery, electrical and control equipment.

4.2.5 In addition to *Pt 1, Ch 2, 4.2 New construction surveys 4.2.4*, the hull construction of craft manufactured from composite materials is to be controlled by a documented quality control system covering the Builder's management, organisation and relevant construction processes and inspection procedures, *see Pt 8, Ch 2 Construction Procedures*.

4.2.6 New craft intended for classification are to be built under LR's Special Survey. The Surveyors are to be satisfied that the materials, workmanship and arrangements are in accordance with the Rules. Any items found not to be in accordance with the Rules or the approved plans, or any material, workmanship or arrangements found be to so, are to be rectified.

4.2.7 For compliance with *Pt 1, Ch 2, 4.2 New construction surveys 4.2.6* LR is prepared to consider methods of survey and inspection for hull construction which formally include procedures involving the shipyard management, organisation and quality systems as defined in Chapter 2 of *Pt 6, Ch 2 Construction Procedures*, *Pt 7, Ch 2 Construction Procedures* and *Pt 8, Ch 2 Construction Procedures*, for steel, aluminium alloy and composite construction respectively.

4.2.8 Copies of approved plans (showing the craft as built), essential certificates and records, required loading and other instruction manuals are to be readily available for use when required by LR's Surveyors and may be required to be kept on board.

4.2.9 After completion, the craft is to be examined afloat, and trials are to be conducted as specified in the Rules.

4.2.10 When the machinery is constructed under LR's Special Survey, this survey is to relate to the period from the commencement of the work until the final test under working conditions. Any items found not to be in accordance with the Rules or the approved plans, or any material, workmanship or arrangements found to be unsatisfactory, are to be rectified.

4.2.11 When arrangements are such that essential machinery can be operated by remote and/or automatic control equipment, the control equipment is to be arranged, installed and tested in accordance with the Rules, as applicable.

4.2.12 The date of completion of the Special Survey during construction of craft built under LR's inspection will normally be taken as the date of build to be entered in the appropriate *Register Book*. If the period between launching and commissioning is, for any reason, unduly prolonged, the dates of launching and completion or commissioning may be separately indicated in the appropriate *Register Book*.

4.2.13 When a craft, upon completion, is not immediately commissioned but is laid-up for a period, the Committee, upon application by the Owner, prior to the craft proceeding to sea, will direct an examination to be made by LR's Surveyors which may include a survey in dry-dock. If, as the result of such survey, the hull and machinery be reported in all respects free from deterioration, the subsequent Special Survey and Complete Survey of the machinery will date from the time of such examination.

4.3 Existing craft

4.3.1 **Classification of craft not built under survey.** The requirements of the Committee for the classification of craft which have not been built under LR's Survey are indicated in *Pt 1, Ch 3, 13 Classification of craft not built under survey* or *Pt 1, Ch 4, 13 Classification of yachts not built under survey* as applicable. Special consideration will be given to craft transferring class to LR from another recognised Classification Society.

4.3.2 **Reclassification.** When reclassification or class reinstatement is desired for a craft for which the class previously assigned by LR has been withdrawn or suspended, the Committee will direct that a survey, appropriate to the age of the craft and the circumstances of the case, be carried out by LR's Surveyors. If, at such survey, the craft be found or placed in a good and efficient condition in accordance with the requirements of the Rules and Regulations, the Committee will be prepared to consider reinstatement of the original class or the assignment of such other class as may be deemed necessary.

4.3.3 In the case of existing yachts over 15 years of age, the requirements for classification of craft not built under survey or for reclassification will be specially considered.

4.3.4 The Committee reserves the right to decline an application for classification or reclassification where the prior history or condition of the ship indicates this to be appropriate.

4.4 Damages, repairs and alterations

4.4.1 All repairs to hull, equipment and machinery which may be required in order that a craft may retain her class, *see Pt 1, Ch 2, 1.1 General 1.1.7*, are to be carried out to the satisfaction of LR's Surveyors. When repairs are effected at a port, terminal or location where the services of a Surveyor to LR are not available, the repairs are to be surveyed by one of LR's Surveyors at the earliest opportunity thereafter.

4.4.2 When at any survey the Surveyors consider repairs to be immediately necessary, either as a result of damage, or wear and tear, they are to communicate their recommendations at once to the Owner, or his representative. When such recommendations are not complied with, immediate notification is to be given to the Committee by the Surveyors.

4.4.3 Where repairs are to be carried out by a riding crew during a voyage then these must be planned in advance. A complete repair procedure, including the extent of proposed repair and the need for Surveyor’s attendance during the voyage, is to be submitted reasonably in advance to the Surveyor for agreement. Failure to notify LR in advance of the repairs may result in the class of the ship being specially considered by the Classification Committee. Where emergency repairs are effected immediately due to an emergency circumstance, the repairs should be documented in the ship’s log and submitted thereafter to LR for use in determining further survey requirements.

4.4.4 When at any survey it is found that any damage, defect, or breakdown (*see Pt 1, Ch 2, 1.1 General 1.1.7*) is of such a nature that it does not require immediate permanent repair, but is sufficiently serious to require rectification by a prescribed date in order to maintain class, a suitable condition of class is to be imposed by the Surveyors and recommended to the Committee for consideration.

4.4.5 If a craft which is classed with LR is to leave harbour limits or protected waters under tow, the Owner is to advise LR of the circumstances prior to her departure.

4.4.6 If a craft which is classed with LR is taken in tow whilst at sea, the Owner is to advise LR of the circumstances at the first practicable opportunity.

4.4.7 Plans and particulars of any proposed alterations to the approved scantlings and arrangements of hull, equipment, or machinery are to be submitted for approval by Owners or Builders or their representatives and such alterations are to be carried out to the satisfaction of LR's Surveyors.

4.4.8 The Owners should notify LR whenever a craft can be examined in dry-dock or on a slipway.

4.5 Existing service craft and yachts - Periodical Surveys

4.5.1 Service craft are to be submitted to the periodical survey requirements as defined in *Pt 1, Ch 3 Periodical Survey Regulations for Service Craft*.

4.5.2 Yachts are to be submitted to the periodical survey requirements defined in *Pt 1, Ch 4 Periodical Survey Regulations for Yachts*, except in the case where LR issues Statutory Loadline SAFCON certification or Certificate of Compliance to 'Code of Practice' as a requirement of the National Authority of the country in which the yacht is registered. In these cases they are to be submitted to the periodical survey requirements as defined in *Pt 1, Ch 3 Periodical Survey Regulations for Service Craft*.

4.5.3 Annual Surveys are to be held on all craft other than yachts within three months, before or after each anniversary of the completion, commissioning or Special Survey. The date of the last Annual Survey will be recorded on the Class Direct website.

4.5.4 Intermediate Surveys are to be held on all craft other than yachts instead of the second or third Annual Survey after completion, commissioning or Special Survey. The date of the last Intermediate Survey will be recorded on the Class Direct website.

4.5.5 Intermediate Surveys are to be held on yachts between the second and third anniversary after completion, commissioning or Special Survey.

4.5.6 The Owner should notify the Surveyors whenever a craft can be examined in dry-dock or on a slipway. A minimum of two Bottom Surveys are to be held in each five-year Special Survey period and the maximum interval between successive Bottom Surveys is not to exceed three years. One of the two Bottom Surveys required in each five-year period is to coincide with the Special Survey. Consideration may be given at the discretion of the Classification Committee to any special circumstances

justifying an extension of the Bottom Survey, not exceeding three months, provided the interval between successive surveys does not exceed 36 months. A Bottom Survey is considered to coincide with the Special Survey when held within the 15 months prior to the date of the Special Survey.

A Bottom Survey is an examination of the outside of the craft's bottom and related items and is normally to be carried out with the craft in dry-dock. However, the Classification Committee may give consideration to alternate examination while the craft is afloat as an In-Water Survey, subject to provisions of *Pt 1, Ch 3, 4.3 In-Water Surveys* and *Pt 1, Ch 4, 3.3 In-Water Surveys*.

Bottom Surveys are to be carried out in accordance with the requirements of *Pt 1, Ch 3, 4 Bottom Surveys – In Dry-Dock and In-Water Surveys - Hull and machinery requirements* and *Pt 1, Ch 4, 3 Bottom Surveys and In-Water Surveys - Hull and machinery requirements*.

4.5.7 The interval between Bottom Surveys for craft operating in fresh water and for certain non self-propelled craft may, at the discretion of the Committee, be greater than that given in *Pt 1, Ch 2, 4.5 Existing service craft and yachts - Periodical Surveys 4.5.6*.

4.5.8 Attention is to be given to any relevant statutory requirements of the National Authority of the country in which the craft is registered.

4.5.9 The date of the last Bottom Survey will be recorded on the Class Direct website.

4.5.10 Survey requirements for In-Water Surveys are given in *Pt 1, Ch 3, 4.3 In-Water Surveys* and *Pt 1, Ch 4, 3.3 In-Water Surveys* as appropriate. The date of the last In-Water Survey will be recorded on the Class Direct website.

4.5.11 All craft classed with LR are also to be subjected to Special Surveys. These Surveys become due at five-yearly intervals, the first one five years from the date of build or date of Special Survey for Classification as recorded in the appropriate *Register Book*, and thereafter five years from the date recorded for the previous Special Survey. Consideration can be given at the discretion of the Committee to any exceptional circumstances justifying an extension of the hull classification to a maximum of three months beyond the fifth year. If an extension is agreed the next period of hull classification will start from the due date of the Special Survey before the extension was granted.

4.5.12 Special surveys may be commenced at the fourth Annual Survey or fourth anniversary, as appropriate, after completion, commissioning, or previous Special Survey, and be progressed during the succeeding year with a view to completion by the due date of the Special Survey.

4.5.13 Special Surveys which are commenced prior to their due date are not to extend over a period greater than 15 months, except with the prior approval of the Committee.

4.5.14 Craft which have satisfactorily passed a Special Survey will have a record entered indicating the date. Where the Special Survey is completed more than three months before the due date, the new record of Special Survey will be the final date of survey. In the case of yachts, this information will be recorded on the Class Direct website.

4.5.15 In all other cases, with the exception of *Pt 1, Ch 2, 4.5 Existing service craft and yachts - Periodical Surveys 4.5.16*, the date recorded will be the fifth anniversary of the previous Special Survey.

4.5.16 For craft registered with Flag Administrations that have neither implemented the International Convention for the Safety of Life at Sea (SOLAS 1974) Harmonised System of Survey and Certification (HSSC) under the Protocol of 1988, nor adopted HSSC under *IMO Resolution A.883(21) – Global and Uniform Implementation of the Harmonized System of Survey and Certification (HSSC) – (Adopted on 25 November 1999)*, where the Special Survey is completed before the due date, the new record will be the final date of survey.

4.5.17 In cases where the ship has been laid-up, or has been out of service for a considerable period because of a major repair or modification and the Owner elects to only carry out the overdue surveys, the next period of class will start from the expiry date of the last Complete Survey of machinery. If the Owner elects to carry out a Complete Survey, the period of class will start from the completion date of this survey.

4.5.18 At the request of an Owner, the Committee may agree that the Special Survey of the hull be carried out on the Continuous Survey basis, all compartments of the hull being opened for survey and testing, in rotation, with an interval of five years between consecutive examinations of each part. In general, approximately one fifth of the Special Survey is to be completed each year and all the requirements of the particular hull Special Survey must be completed at the end of the five year cycle. If the examination during Continuous Survey reveals any defects, further parts are to be opened up and examined as considered necessary by the Surveyor. For examination of items listed in *Pt 1, Ch 3, 2.2 Annual Surveys 2.2.18*, *Pt 1, Ch 3, 2.2 Annual Surveys 2.2.20*, *Pt 1, Ch 3, 3.2 Intermediate Surveys 3.2.2*, *Pt 1, Ch 3, 3.2 Intermediate Surveys 3.2.3*, *Pt 1, Ch 3, 3.2 Intermediate Surveys 3.2.4* or *Pt 1, Ch 4, 2.2 Intermediate Surveys 2.2.11*, *Pt 1, Ch 4, 2.2 Intermediate Surveys 2.2.12*, *Pt 1, Ch*

4, 2.2 Intermediate Surveys 2.2.13 as applicable, the intervals for inspection will require to be specially agreed. Craft which have satisfactorily completed the cycle will have a record entered in the *Register Book* indicating the date of completion which will not be later than five years from the last assigned date of Complete Survey of the hull. The agreement for surveys to be carried out on Continuous Survey basis may be withdrawn at the discretion of the Committee.

4.5.19 In cases where the craft has been laid up or has been out of service for a considerable period because of a major repair or modification and the Owner elects to only carry out the overdue surveys, the next period of class will start from the expiry date of the Special Survey. If the Owner elects to carry out the next due Special Survey, the period of class will start from the survey completion date.

4.5.20 Complete Surveys of machinery become due at five-yearly intervals, the first one five years from the date of build or date of first classification as recorded in the appropriate *Register Book*, and thereafter five years from the date recorded for the previous Complete Survey. Consideration can be given at the discretion of the Classification Committee to any exceptional circumstances justifying an extension of machinery class to a maximum of three months beyond the fifth year. If an extension is agreed to, the next period of machinery class will start from the due date of Complete Survey of machinery before extension was granted. Surveys which are commenced prior to their due date are not to extend over a period greater than 15 months, except with the prior approval of the Classification Committee. Where the complete survey is completed more than three months before the due date, the recorded date of completion will be the final date of survey.

(a) In all other cases, with the exception of *Pt 1, Ch 2, 4.5 Existing service craft and yachts - Periodical Surveys 4.5.20.(b)*, the date recorded will be the fifth anniversary of the previous Complete Survey of machinery.
(b) For craft registered with Flag Administrations that have neither implemented the International Convention for the Safety of Life at Sea (SOLAS 1974) Harmonised System of Survey and Certification (HSSC) under the Protocol of 1988, nor have adopted HSSC under *IMO Resolution A.883(21) – Global and Uniform Implementation of the Harmonized System of Survey and Certification (HSSC) – (Adopted on 25 November 1999)*, where the Survey is completed before the due date, the new record will be the final date of survey.

4.5.21 Upon application by an Owner, the Committee may agree to the extension of the survey requirements for main engines, which, by the nature of the craft's normal service, do not attain the number of running hours recommended by the engines' manufacturer for major overhauls within the survey periods given in *Pt 1, Ch 2, 4.5 Existing service craft and yachts - Periodical Surveys 4.5.20*.

4.5.22 If it is found desirable that any part of the machinery should be examined again before the due date of the next survey, a certificate for a limited period will be granted in accordance with the nature of the case.

4.5.23 When, at the request of an Owner, it has been agreed by the Committee that the Complete Survey of the machinery may be carried out on the Continuous Survey basis, the various items of machinery are to be opened for survey in rotation, so far as is practicable, to ensure that the interval between consecutive examinations of each item will not exceed five years. In general, approximately one-fifth of the machinery is to be examined each year.

4.5.24 If any examination during Continuous Survey reveals defects, further parts are to be opened up and examined as considered necessary by the Surveyor, and the defects are to be made good to his satisfaction.

4.5.25 Upon application by an Owner, the Committee may agree to an arrangement whereby, subject to certain conditions, some items of machinery may be examined by the Chief Engineer of the craft at ports where LR is not represented, or, where practicable, at sea, followed by a limited confirmatory survey carried out at the next port of call where an Exclusive Surveyor is available. Particulars of this arrangement may be obtained from LR's Headquarters.

4.5.26 Where an approved planned maintenance scheme is in operation the confirmatory surveys of machinery as required by *Pt 1, Ch 2, 4.5 Existing service craft and yachts - Periodical Surveys 4.5.24* may be held at annual intervals, at which time the records will be checked and the operation of the scheme verified. Particulars of this arrangement may be obtained from any of LR's Offices.

4.5.27 Where condition monitoring equipment is fitted, the Committee, upon application by the Owner, will be prepared to amend applicable Periodical Survey requirements where details of the equipment are submitted and found satisfactory. Where machinery installations are accepted for this method of survey, it will be a requirement that an Annual Survey be held, at which time monitored records will be analysed and the machinery examined under working conditions. An acceptable lubricating oil trend analysis programme may be required as part of the condition monitoring procedures.

4.5.28 Screwshaft and Waterjet Unit Surveys are to be carried out as stated in *Pt 1, Ch 3, 12 Screwshafts, tube shafts, propellers and water jet units* for service craft and *Pt 1, Ch 4, 11 Screwshafts, tube shafts, propellers and water jet units* for yachts.

4.5.29 Boiler surveys and steam pipe surveys, where applicable, are to be carried out as stated in accordance with Pt 1, Ch 3, *Pt 1, Ch 3, 15 Boilers* and *Pt 1, Ch 3, 16 Steam pipes* of the Rules for Ships.

4.5.30 Craft of unusual design, type or arrangement may be subject to exceptional survey requirements. Such survey requirements will be detailed at the assignment of classification.

4.5.31 Where the Committee has agreed to an Owner's request to assign the **Laid-up** notation, the vessel may be retained in class provided a satisfactory general examination of the hull and machinery is carried out at the Annual Survey/Intermediate Survey due date and in addition an Underwater Examination (UWE) is carried out at the Special Survey due date. The general examination may be carried out within three months before or after the Annual Survey due date.

4.6 Existing amphibious air cushion vehicles - Periodical Surveys

4.6.1 Amphibious Air Cushion Vehicles are to be submitted to the periodical survey requirements as defined in *Pt 1, Ch 5 Periodical Survey Regulations for Amphibious Air Cushion Vehicles (ACV)*.

4.7 Surveys for novel/complex systems, machinery and equipment

4.7.1 Where novel/complex systems, machinery and equipment have been accepted by LR, and for which existing survey requirements are not considered to be suitable and sufficient then, appropriate survey requirements are to be derived as part of the design approval process. In deriving these requirements LR will consider, but not be limited to, the following:

(a) Plan appraisal submissions;
(b) Risk Assessment documentation where required by the Rules;
(c) Equipment manufacturer recommendations;
(d) Relevant recognised national or international standards.

4.8 Certificates

4.8.1 When the required reports, on completion of the survey of new or existing craft which have been submitted for classification, have been received from the Surveyors and approved by the Committee, a certificate of First Entry of Classification, signed by the Chairman, or the Deputy Chairman and Chairman of the Sub-Committee of Classification, will be issued to Builders or Owners.

4.8.2 A Certificate of Class valid for five years subject to endorsement for Annual and/or Intermediate Surveys, as appropriate, will also be issued to the Owners.

4.8.3 LR's Surveyors are permitted to issue provisional (interim) certificates to enable a craft classed with LR to proceed on her voyage provided that in their opinion it is in a fit and efficient condition. Such certificates will embody the Surveyors' recommendations for continuance of class, but in all cases are subject to confirmation by the Committee.

4.9 Notice of surveys

4.9.1 It is the responsibility of the Owners to ensure that all surveys necessary for the maintenance of class are carried out at the proper time and in accordance with the instructions of the Committee. Information is available to Owners on the Class Direct website.

4.9.2 LR will give timely notice to an Owner about forthcoming surveys by means of a letter or a computer print-out of a craft's *Quarterly Listing of Surveys, Conditions of Class and Memoranda*. The omission of such notice, however, does not absolve the Owner from his responsibility to comply with LR's survey requirements for maintenance of class, all of which are available to Owners on the Class Direct website.

4.10 Withdrawal/Suspension of class

4.10.1 When the class of a craft, for which the Regulation as regards surveys on hull, equipment and machinery have been complied with, is withdrawn by the Committee in consequence of a request from the Owner the notation `Class withdrawn at Owner's request' (with date) will be assigned.

4.10.2 When the Regulations as regards surveys on the hull, equipment or machinery have not been complied with and the craft is thereby not entitled to retain class, the class will be suspended or withdrawn, at the discretion of the Committee, and a corresponding notation will be assigned.

4.10.3 Class will be automatically suspended and the Certificate of Class will become invalid if the Annual or Intermediate Survey, as appropriate, is not completed within three months of the due date of the survey.

4.10.4 Class will be automatically suspended from the expiry date of the Certificate of Class in the event that the Special Survey has not been completed by the due date and an extension has not been agreed (*see Pt 1, Ch 2, 4.5 Existing service craft and yachts - Periodical Surveys 4.5.11*), or is not under attendance by the Surveyors with a view to completion prior to resuming trading.

Classification will be reinstated from suspension of class upon satisfactory completion of the surveys due. The surveys to be carried out are to be based upon the survey requirements at the original date due and not on the age of the craft when the survey is carried out. Such surveys are to be credited from the date originally due. However, the craft's Class remains suspended from the date of suspension until the date Class is reinstated.

4.10.5 When in accordance with *Pt 1, Ch 2, 4.4 Damages, repairs and alterations 4.4.4* a condition of class is imposed, this will be assigned a due date for completion and the craft's class will be subject to a suspension procedure if the condition of class is not dealt with, or postponed by agreement, by the due date.

4.10.6 When it is found, from the reported condition of the hull or equipment or machinery of a craft, that an Owner has failed to comply with Regulations *Pt 1, Ch 2, 1.1 General 1.1.7*, *Pt 1, Ch 2, 1.1 General 1.1.11*, *Pt 1, Ch 2, 4.4 Damages, repairs and alterations 4.4.1* or *Pt 1, Ch 2, 4.4 Damages, repairs and alterations 4.4.6* above, the class will be liable to be suspended or withdrawn, at the discretion of the Committee, and a corresponding notation assigned. When it is considered that an Owner's failure to comply with these requirements is sufficiently serious the suspension or withdrawal of class may be extended to include other craft controlled by the same Owner, at the discretion of the Committee.

4.10.7 When any craft proceeds to sea with less freeboard than that approved by the Committee, or when the freeboard marks are placed higher on the sides of the craft than the position assigned or approved by the Committee, or, in cases of craft where freeboards are not assigned, the draught is greater than that approved by the Committee, the class will be liable to be withdrawn or suspended.

4.10.8 When it is found that a craft is being operated in a manner contrary to that agreed at the time of classification, i.e. out with the parameters of the operational envelope, the class will be liable to be automatically withdrawn or suspended.

4.10.9 In all instances of class withdrawal or suspension, the assigned notation, with date of application, will appear in the *Register Book*. In cases where class has been suspended by the Committee and it becomes apparent that the Owners are no longer interested in retaining LR's class, the notation will be amended to withdrawn status. After class withdrawn status has been established in the appropriate *Register Book* for one year, it will be automatically amended to `classed LR until' (with date). In the case of yachts this information will be recorded on the Class Direct website.

4.10.10 When a vessel is intended for a demolition voyage with any Periodical Survey overdue, the vessel's class suspension may be held in abeyance and consideration may be given to allow the vessel to proceed on a single direct ballast voyage from the lay up or final discharge port to the demolition yard, provided the attending Surveyor finds the vessel in a satisfactory condition to proceed for the intended voyage, at the discretion of the Classification Committee.

4.10.11 When a vessel is intended for a single voyage from 'laid-up' position to repair yard with any Periodical Survey overdue, the vessel's class suspension may be held in abeyance and consideration may be given to allow the vessel to proceed on a single direct ballast voyage from the site of lay up to the repair yard, upon agreement with the Flag Administration, at the discretion of the Classification Committee. This is provided the vessel is found in a satisfactory condition by surveys, the extent of which are to be based on surveys overdue and duration of lay-up.

4.10.12 For reclassification and reinstatement of class, *see Pt 1, Ch 2, 4.3 Existing craft 4.3.2*, *Pt 1, Ch 2, 4.3 Existing craft 4.3.3* and *Pt 1, Ch 2, 4.10 Withdrawal/Suspension of class 4.10.4*.

4.11 Survey of craft out of commission

4.11.1 The classification requirements for laid up vessels will be specially considered. Surveys for continuation of class may be required at the discretion of the Committee.

4.12 Appeal from Surveyors' recommendations

4.12.1 If the recommendations of LR's Surveyors are considered in any case to be unnecessary or unreasonable, appeal may be made to the Committee, who may direct a Special Examination to be held.

4.13 Force majeure

4.13.1 If due to circumstances reasonably beyond the Owner's or LR's control, as defined below, the vessel is not in a port when surveys become overdue the Classification Committee may allow the vessel to sail, in class, directly to an agreed discharge port and then, if necessary, in ballast to an agreed repair facility at which the survey can be completed. In this context, 'Force

Majeure' means damage to the vessel, unforeseen inability of Surveyors to attend the vessel due to governmental restrictions on right of access or movement of personnel, unforeseen delays in port or inability to discharge cargo due to unusually lengthy periods of severe weather, strikes, civil strife, acts of war or other force majeure.

4.13.2 In circumstances of global disruption to normal maritime operations, such as experienced during the global COVID-19 pandemic, where Flag Administrations adopt extraordinary measures permitting postponements to scheduled statutory surveys beyond the due dates, the Classification Committee may allow corresponding postponements to scheduled class surveys provided the following measures to confirm the continued compliance of the vessel with LR classification requirements are undertaken:

(a) a confirmatory LR examination of the ship's records; and,
(b) an LR review of evidence submitted by the Owner that confirms that the vessel is in a condition to satisfactorily continue in class for the agreed period of postponement; this may include an LR remote survey, and provision to LR of acceptable photographic, video or other evidence of condition of structure or equipment; and,
(c) receipt of a confirmatory statement from the Master advising that the ship is, in their opinion, in compliance with LR's *Rules and Regulations* and in a condition to satisfactorily continue in service for the agreed period; and,
(d) any due and/or overdue surveys and examination of Conditions of Class, Actionable Items and Statutory Findings are to be carried out at the first port of call with available facilities where LR Surveyors can reasonably attend to complete the overdue surveys.

4.14 Ownership details

4.14.1 The Owner will ensure a member of the LR Group - Marine and Offshore division is promptly informed in writing of any change to their contact details and, in the event of a vessel/asset transfer or sale, is to supply details of the new Owner in writing. The new Owner is to promptly inform a member of the LR Group - Marine and Offshore division in writing of their contact details. If the new Owner fails to do so and if LR cannot verify the ownership record, then the class of that vessel/asset will be specially considered by the Classification Committee.

■ *Section 5*
IACS QSCS Audits

5.1 Audit of Surveys

5.1.1 The surveys required by the Regulations may be subject to audit in accordance with the requirements of the International Association of Classification Societies Quality System Certification Scheme.

■ *Section 6*
Type Approval/Type testing

6.1 LR Type Approval — Marine Applications

6.1.1 LR Type Approval is an impartial certification system that provides independent third-party Type Approval Certificates attesting to a product's conformity with specific standards or specifications. It is based on design review and type testing or where testing is not appropriate, a design analysis.

6.1.2 The LR Type Approval System is a process whereby a product is assessed in accordance with a specification, standard or code to check that it meets the stated requirements and through selective testing demonstrates compliance with specific performance requirements. The testing is carried out on a prototype or randomly selected product(s) which are representative of the manufactured product under approval. Thereafter, the manufacturer applying for LR Type Approval certification is required to demonstrate the effective implementation of a quality assurance system. This will be assessed by LR through a Production Quality Assurance (PQA) assessment as defined in the Lloyd's Register Type Approval System Procedure TA14. The PQA assessment is specific to Lloyd's Register Type Approval.

6.1.3 The selective testing required by *Pt 1, Ch 2, 6.1 LR Type Approval — Marine Applications 6.1.2* is to include environmental testing applicable to the product's installation on board a craft or yacht classed or intended to be classed with LR.

6.1.4 LR Type Approval does not remove the requirements for inspection and survey procedures required by the Rules for equipment to be installed in craft/yachts classed or intended to be classed with LR. Also, LR Type Approval does not remove the requirement for plan appraisal of a system that incorporates Type Approved equipment where required by the Rules.

6.1.5 LR Type Approval is subject to the understanding that the manufacturer's recommendations and instructions for the product and any relevant requirements of the *Rules and Regulations for the Classification of Special Service Craft, July 2021* are fulfilled.

6.1.6 The manufacturer supplying equipment or components under the system for production quality assurance (PQA) *see Pt 1, Ch 2, 6.1 LR Type Approval — Marine Applications 6.1.2* is to have a recognised quality management system that is acceptable to LR. The system for production quality assurance are to address the production of the product consistent with is to meet the requirements of Lloyd’s Register Type Approval System Procedure TA14.

6.1.7 Where equipment or components have been Type Approved in accordance with specifications and procedures other than LR's, details of the product, certification and testing are to be submitted for consideration where appropriate.

6.2 Type testing

6.2.1 Type testing is an impartial process that provides independent third-party verification that an item of machinery or equipment has satisfactorily undergone a functional type test.

6.2.2 Type testing is carried out against defined performance and test standards for a defined period of time with test conditions varying between minimum and maximum declared design conditions.

6.2.3 Type testing is carried out on a prototype or randomly selected product(s) which are representative of the manufactured product under assessment.

6.2.4 After type testing, mechanical equipment is to be opened out and inspected for damage or excessive wear.

6.2.5 On application from the manufacturer, type tests may be waived for equipment and machinery that has been proven to be reliable in marine service and where compliance with the current applicable standards can be demonstrated. Equipment and machinery that has been previously type tested with satisfactory testing evidence and certification need not have the type tests repeated where previous testing is in compliance with the current testing standards.

6.2.6 The acceptance of type testing certification is subject to the understanding that the manufacturer's recommendations and instructions for the product and any relevant requirements of the applicable Rules are fulfilled.

6.3 Mutual Recognition of Type Approval certificates

6.3.1 In accordance with Article 10.1 of Regulation (EC) No. 391/2009 pertaining to Mutual Recognition of Class certificates, LR is obliged to mutually recognise MR Type Approval certificates for products as defined in the European Union Recognised Organisation Mutual Recognition Group product list which are MR type approved by other Recognised Organisations (ROs).

6.3.2 The current list of such items and the conditions for mutual recognition are described at *www.euromr.org*.

■ *Section 7*
Classification of machinery for crafts/yachts with [✠]LMC or MCH notation

7.1 General

7.1.1 After delivery of machinery and equipment with the manufacturer's certificate to the build yard, Survey at the build yard and Periodical Surveys are to be in accordance with the requirements for craft/yacht built or accepted into class with the ✠ **LMC** notation.

7.2 Appraisal and records

7.2.1 To facilitate survey and compilation of classification records, plans and information required for a craft/yacht being accepted into class with the ✠ **LMC** notation are to be submitted for appraisal and information. Plans are not required where machinery and equipment has previously been type approved; in these cases it is only necessary to submit details of the machinery and equipment together with details of the previous approval.

7.3 Survey and inspection

7.3.1 The manufacturer's certificate for acceptance of machinery and equipment for assignment of the [✠] **LMC** or **MCH** notation is to be in the English language and include the following information:

(a) Design and manufacturing standard(s) used.
(b) Materials used for construction of key components and their sources.
(c) Details of the quality control system applied during design, manufacture and testing and any software maintenance.
(d) Details of any type approval or type testing.
(e) Details of installation and testing recommendations for the machinery or equipment.

The manufacturer is to have a recognised quality management system certified by an IACS member or a Notified Body.

7.3.2 The installation and testing of machinery and equipment at the build yard which has been supplied with a manufacturer's certificate is to be in accordance with the requirements applicable to a craft/yacht having the ✠ **LMC** notation.

■ *Section 1* General

1.1 Frequency of surveys

1.1.1 The requirements of this Chapter are applicable to the Periodical Surveys set out in *Pt 1, Ch 2, 4.5 Existing service craft and yachts - Periodical Surveys*. Except as amended at the discretion of the Committee, the periods between such surveys are as follows:

(a) Annual Surveys, as required by *Pt 1, Ch 2, 4.5 Existing service craft and yachts - Periodical Surveys 4.5.3*.
(b) Intermediate Surveys as required by *Pt 1, Ch 2, 4.5 Existing service craft and yachts - Periodical Surveys 4.5.4*.
(c) Bottom Surveys as required by *Pt 1, Ch 2, 4.5 Existing service craft and yachts - Periodical Surveys 4.5.6* and *Pt 1, Ch 2, 4.5 Existing service craft and yachts - Periodical Surveys 4.5.7*.
(d) Special Surveys at five-yearly intervals, *see Pt 1, Ch 2, 4.5 Existing service craft and yachts - Periodical Surveys 4.5.11*. For alternative arrangements, *see also Pt 1, Ch 2, 4.5 Existing service craft and yachts - Periodical Surveys 4.5.12*, *Pt 1, Ch 2, 4.5 Existing service craft and yachts - Periodical Surveys 4.5.13* and *Pt 1, Ch 2, 4.5 Existing service craft and yachts - Periodical Surveys 4.5.18*.
(e) Complete Surveys of machinery at five-yearly intervals, *see Pt 1, Ch 2, 4.5 Existing service craft and yachts - Periodical Surveys 4.5.20*. For alternative arrangements, *see also Pt 1, Ch 2, 4.5 Existing service craft and yachts - Periodical Surveys 4.5.21*, *Pt 1, Ch 2, 4.5 Existing service craft and yachts - Periodical Surveys 4.5.23*, *Pt 1, Ch 2, 4.5 Existing service craft and yachts - Periodical Surveys 4.5.26* and *Pt 1, Ch 2, 4.5 Existing service craft and yachts - Periodical Surveys 4.5.27*.

1.1.2 For craft assigned the **Laid-up** notation, in order to maintain the craft in class a general examination of the hull and machinery is to be carried out in lieu of the Annual Survey/Intermediate Survey and in addition an Underwater Examination (UWE) is to be carried out in lieu of the Special Survey, *see Pt 1, Ch 3, 2.1 General 2.1.3*, *Pt 1, Ch 3, 5.1 General 5.1.4* and *Pt 1, Ch 3, 7.1 Annual, Intermediate and Bottom Surveys 7.1.3*.

1.1.3 When it has been agreed that the complete survey of the hull and machinery may be carried out on the Continuous Survey basis, all compartments of the hull and all items of machinery are to opened for survey in rotation to ensure that the interval

between consecutive examinations of each part will not exceed five years, *see* Ch 2,*Pt 1, Ch 2, 4.5 Existing service craft and yachts - Periodical Surveys 4.5.19* and *Pt 1, Ch 2, 4.5 Existing service craft and yachts - Periodical Surveys 4.5.23*.

1.1.4 For the frequency of surveys of screwshafts, tube shafts, propellers and water jet units, *see Pt 1, Ch 3, 12 Screwshafts, tube shafts, propellers and water jet units*.

1.2 Surveys for damage or alterations

1.2.1 At any time when a craft is undergoing alterations or damage repairs, any exposed parts of the structure normally difficult to access are to be specially examined, e.g. if any part of the main or auxiliary machinery is removed for any reason, the hull structure in way is to be carefully examined by the Surveyor, or when cement in the bottom or sheathing on decks is removed, the structure in way is to be examined before the cement or sheathing is relaid.

1.3 Unscheduled surveys

1.3.1 In the event that Lloyd's Register (hereinafter referred to as 'LR') has cause to believe that its Rules and Regulations are not being complied with, LR reserves the right to perform unscheduled surveys of the hull and machinery as well as the applicable statutory requirements whether or not the appropriate statutory certificate has been issued by LR.

1.3.2 In the event of significant damage or defect affecting any craft, LR reserves the right to perform unscheduled surveys of the hull or machinery of other similar craft classed by LR and deemed to be vulnerable.

1.4 Surveys for the issue of Convention certificates

1.4.1 Surveys are to be held either by LR when so appointed, or by the Exclusive Surveyors to a National Administration or by an IACS Member when so authorised by the National Authority, or, in the case of Cargo Ship Safety Radio Certificates or Safety Management Certificates, by any organisation authorised by the National Authority. In the case of dual classed craft, Convention certificates may be issued by the other Society with which the craft is classed provided this is recognised in a formal Dual Class Agreement with LR and provided the other Society is also authorised by the National Authority.

1.5 Definitions

1.5.1 A **Ballast Tank** is a tank which is used solely for salt water ballast. A tank which is used for both cargo and salt water ballast will be treated as a salt water ballast tank when substantial corrosion has been found in that tank.

1.5.2 **Spaces** are separate compartments such as holds, tanks, cofferdams and void spaces bounding cargo holds, decks and the outer hull.

1.5.3 **Enclosed space.** An enclosed space is any place of an enclosed nature where there is a risk of death or serious injury from hazardous substances or dangerous conditions. Examples include, but are not limited to: boilers, pressure vessels, cargo spaces (cargo holds or cargo tanks), cargo space stairways, ballast tanks, double bottoms, double hull spaces, fuel oil tanks, lube oil tanks, sewage-tanks, pump-rooms, compressor rooms, cofferdams, void spaces, duct keels, inter-barrier spaces, engine crankcases, excavations and pits.

1.5.4 **Suspect areas** are locations within the hull structure vulnerable to increased likelihood of structural deterioration and may include:

(a) For steel hulls, areas of substantial corrosion and/or fatigue cracking.
(b) For aluminium alloy hulls, areas of fatigue cracking and areas in the vicinity of bimetallic connections.
(c) For composite hulls, areas subject to impact damage.
(d) For high speed craft (as defined in *Pt 1, Ch 2, 2.2 Definitions 2.2.7*), areas of the bottom structure forward prone to slamming damage.

1.5.5 **Substantial corrosion** is wastage of individual steel or aluminium plates and stiffeners in excess of 75 per cent of allowable margins, but within acceptable limits.

1.5.6 **Protective coatings** for steel craft should usually be hard coatings. Other coating systems (e.g. soft coating) may be considered acceptable as alternatives provided they are applied and properly maintained in compliance with the manufacturer's specification.

1.5.7 **Coating condition** for steel craft is defined as follows:

GOOD	Condition with only minor spot rusting.
FAIR	Condition with local breakdown of coating at edges of stiffeners and weld connections and/or light rusting over 20 per cent or more of areas under consideration, but less than as defined for POOR condition.
POOR	Condition with general breakdown of coating over 20 per cent or more of areas or hard scale at 10 per cent or more of areas under consideration.

1.5.8 A **Prompt and Thorough Repair** is a permanent repair completed at the time of survey to the satisfaction of the Surveyor, therein removing the need for the imposition of any associated condition of class or recommendation.

1.5.9 **Air pipe heads** installed on the exposed decks are those extending above the freeboard deck or superstructure decks.

1.6 Repairs

1.6.1 Any damage in association with wastage over the allowable limit (including buckling, grooving, detachment or fracture), or extensive areas of wastage over the allowable limits, which affects or, in the opinion of the Surveyor, will affect the craft's structural, watertight or weathertight integrity, is to be promptly and thoroughly repaired. Areas to be considered include, (where fitted):

- side shell frames, their end attachments and adjacent shell plating;
- deck structure and deck plating;
- bottom structure and bottom plating;
- side structure and side plating;
- inner bottom structure and inner bottom plating;
- inner side structure and inner side plating;
- watertight or oiltight bulkheads;
- hatch covers and hatch coamings;
- the weld connection between air pipes and deck plating;
- air pipe heads installed on the exposed decks;
- ventilators, including closing devices.

For locations where adequate repair facilities are not available, consideration may be given to allow the craft to proceed directly to a repair facility. This may require discharging the cargo and/or temporary repairs for the intended voyage.

1.6.2 Additionally, when a survey results in the identification of structural defects or corrosion, either of which, in the opinion of the Surveyor, will impair the craft's fitness for continued service, remedial measures are to be implemented before the craft continues in service.

1.6.3 Where the damage found on structure mentioned in *Pt 1, Ch 3, 1.6 Repairs 1.6.1* is isolated and of a localised nature which does not affect the craft's structural integrity (as, for example, a localised, isolated and very minor hole in a cross-deck strip), consideration may be given by the Surveyor to allow an appropriate temporary repair to restore watertight or weathertight integrity after careful evaluation of the surrounding structure and impose an associated Condition of Class with a specific short-term time limit in order to complete the repair and retain classification.

1.7 Preparation for survey and means of access

1.7.1 In order to enable the attending Surveyor(s) to carry out surveys, provisions for safe access and for surveys are to be agreed between the Owner and LR. Attention is drawn to the applicable recommendations in the IACS PR37 and/or IMO Recommendations For Entering Enclosed Spaces Aboard Ships, Resolution A.1050(27).

1.7.2 Means are to be provided to enable the Surveyor to examine the structure in a safe and practical way. Where the provisions of safety and required access are determined by the Surveyor not to be adequate, then the survey of the space(s) involved is not to proceed.

1.7.3 Spaces are to be made safe for access and surveys and are to be sufficiently cleaned, illuminated and ventilated.

1.7.4 In preparation for surveys, thickness measurements and to allow for a thorough examination, cleaning is to include removal from surfaces of all loose accumulated corrosion scale. Spaces are to be sufficiently clean and free from water, scale, dirt, oil residues, etc. to reveal corrosion, deformation, fractures, damages or other structural deterioration, as well as the condition of

the protective coating. However, those areas of structure whose renewal has already been decided by the Owner need only be cleaned and descaled to the extent necessary to determine the limits of renewed areas.

1.7.5 Where soft or semi-hard coatings have been applied, safe access is to be provided for the Surveyor to verify the effectiveness of the coating and to carry out an assessment of the conditions of internal structures which may include spot removal of the coating. When safe access cannot be provided, the soft or semi-hard coating is to be removed.

1.7.6 Prior to entering an enclosed space, it is to be verified by a competent person using a calibrated multi-gas meter that the atmosphere in that space is free from hazardous gas and contains sufficient oxygen.

1.7.7 Emergency equipment and personnel are to be available in case of an emergency or rescue operation.

1.7.8 Information on procedures, equipment operating instructions and safety checklists is to be available.

1.7.9 During the survey, ventilation is to be ensured and periodic testing is to be carried out as necessary to verify that the atmosphere remains safe for access.

■ *Section 2*
Annual Surveys - Hull and machinery requirements

2.1 General

2.1.1 Annual Surveys are to be held concurrently with any relevant statutory annual or other statutory surveys, wherever practicable.

2.1.2 At Annual Surveys, the Surveyor is to examine the hull and machinery, so far as necessary and practicable, in order to be satisfied as to their general condition.

2.1.3 For vessels assigned the **Laid-up** notation, in lieu of the normal Annual Survey requirements a general examination of the hull and machinery is to be carried out.

2.2 Annual Surveys

2.2.1 The Surveyor is to be satisfied regarding:

(a) The efficient condition of hatchways on freeboard and superstructure decks, weather deck plating, hull above the waterline, ventilator coamings and air pipes, exposed casings, skylights, flush deck scuttles, deckhouses and companionways, superstructure bulkheads, side, bow and stern doors, windows and storm shutters, side scuttles and deadlights, chutes and other openings, together with all closing appliances and flame screens.

(b) The efficient condition of watertight penetrations as far as practicable. Where applicable, the electrical cables schedule of watertight penetrations (e.g. cable transit seal systems register) is to be reviewed to confirm it is being maintained, *see Pt 4, Ch 1, 4.5 Plans to be supplied to the unit* and *Pt 16, Ch 2, 11.11 Penetration of bulkheads and decks by cables*.

(c) The efficient operating condition of mechanically operated hatch covers including stowage, fit, securing, locking, sealing and operational testing of hydraulic power components, wires, chains, etc.

(d) The efficient condition of scuppers and sanitary discharges (so far as is practicable); valves on discharge lines (so far as is practicable) and their controls; guard rails and bulwarks; freeing ports, gangways and life-lines; fittings and appliances for timber deck cargoes.

(e) The efficient condition of bilge level detection and alarm systems on craft assigned a **UMS** notation.

2.2.2 Any cargo hatch covers and coamings together with any cargo doors or ramps which form part of the watertight integrity of the hull are to be examined to ensure that no alterations have been made to the approved arrangements.

(a) Mechanically operated cargo hatch covers or doors are to be tested for tightness and to confirm the satisfactory condition of securing and sealing arrangements; drainage channels; operating mechanisms; tracks and wheels.

(b) Cargo hatch covers of the portable type are to be examined to confirm that the covers and closing appliances are in a satisfactory condition.

2.2.3 The anchoring and mooring equipment including anchor warps or wire ropes is to be examined so far as is practicable.

2.2.4 The watertight doors in watertight bulkheads, their indicators and alarms are to be examined and operationally tested locally and where applicable remotely. Other watertight bulkhead penetrations are to be examined so far as is practicable.

2.2.5 The Surveyor is to examine and test in operation all main and auxiliary steering arrangements including their associated equipment and control systems, and verify that log book entries have been made in accordance with statutory requirements where applicable.

2.2.6 Where applicable, the Surveyor is to be satisfied regarding the freeboard marks on the craft's side.

2.2.7 The Surveyor is to generally inspect the machinery spaces with particular attention being given to the propulsion system, auxiliary machinery and to the existence of any fire and explosion hazards. Where applicable, emergency escape routes are to be checked to ensure that they are free of obstruction.

2.2.8 The means of communication between the navigating bridge and the machinery control positions, as well as the bridge and the alternative steering position, if fitted, are to be tested.

2.2.9 The bilge pumping systems for each watertight compartment, including bilge wells, extended spindles, self-closing drain cocks, valves fitted with rod gearing or other remote operation, pumps and level alarms, where fitted, are to be examined and operated as far as practicable and all confirmed to be satisfactory. Any hand pumps provided are to be included.

2.2.10 The boilers, other pressure vessels and their appurtenances, including foundations, controls, high pressure and waste steam piping, and insulation and gauges, are to be generally examined. Surveyors should confirm that Periodical Surveys of boilers and other pressure vessels have been carried out as required by the Rules.

2.2.11 For boilers, the safety devices are to be tested, and the safety valves are to be operated using the relieving devices. For exhaust gas heated economisers/boilers, the safety valves are to be tested at sea by the Chief Engineer and details recorded in the log book.

2.2.12 The operation and maintenance records, repair history and feed water chemistry records of boilers are to be examined.

2.2.13 For other pressure vessels, the safety devices are to be examined.

2.2.14 Where lithium battery system installations are used as a power source for essential or emergency systems, testing is to be conducted in accordance with the trials requirements in *Pt 16 Control and Electrical Engineering*, *Table 2.21.2 Test requirements on lithium battery systems*. Additionally the following aspects of the battery space are to be inspected, as applicableto the installation:

(a) structural fire protection;
(b) fixed fire detection;
(c) HVAC, ventilation, cooling, smoke extraction, fire damper systems;
(d) fixed and portable extinguishing; and
(e) escape and EEBD (emergency escape breathing device).

2.2.15 The electrical equipment and cabling forming the main and emergency electrical installations are to be generally examined under operating conditions so far as is practicable. The satisfactory operation of the main and emergency sources of power and electrical services essential for safety in an emergency is to be verified; where the sources of power are automatically controlled they should be tested in the automatic mode. Bonding straps for the control of static electricity and earthing arrangements are to be examined where fitted.

2.2.16 For main propulsion, essential auxiliary and emergency machinery control engineering systems, a general examination of the equipment and arrangements is to be carried out. Records of modifications are to be made available for review by the attending Surveyor. The documentation required by *Pt 6, Ch 1 General*, including configuration management, are to be reviewed following system modifications. Satisfactory operation of the safety devices and control systems is to be verified. For craft having **UMS** or **CCS** notation, a general examination of the control engineering equipment required for these notations is also to be carried out.

2.2.17 For craft fitted with an electronically controlled engine for main propulsion, essential auxiliary or emergency power purposes, the following is to be carried out to the satisfaction of the Surveyor:

(a) Verification of evidence of satisfactory operation of the engine and, where possible, this is to include a running test under load;
(b) Verification of satisfactory operation of the safety devices and control, alarm and monitoring systems; and
(c) Verification that any changes to the software or control, alarm, monitoring and safety systems that affect the operation of the engine have been assessed by LR and are under configuration management control.

2.2.18 For craft to which *Pt 17, Ch 1 Fire Protection, Detection and Extinction – General* applies, the arrangements for fire protection, detection and extinction are to be examined and are to include the following items, as required to be fitted in accordance with the Rules:

(a) Verification, so far as is practicable, that no significant changes have been made to the arrangement of structural fire protection.
(b) Verification of the operation of manual and/or automatic doors where fitted.
(c) Verification that fire control plans are properly posted.
(d) Examination, so far as is possible, and testing as feasible, of the fire and/or smoke detection and alarm system(s).
(e) Examination of fire main system, and confirmation that each fire pump, including the emergency fire pump can be operated separately so that the required jets of water can be produced simultaneously from different hydrants.
(f) Verification that fire-hoses, nozzles, applicators and spanners are in good working condition and situated at their respective locations.
(g) Examination of fixed fire-fighting systems controls, piping, instructions and marking, checking for evidence of proper maintenance and servicing, including date of last systems tests.
(h) Verification that all portable and semi-portable fire-extinguishers are in their stowed positions, checking for evidence of proper maintenance and servicing, conducting random checks for evidence of discharged containers.
(i) Verification, so far as is practicable, that the remote control for stopping fans and machinery and shutting off fuel supplies in machinery spaces and, where fitted, the remote controls for stopping fans in accommodation spaces and the means of cutting off power to the galley are in good working order.
(j) Examination of the closing arrangements of ventilators, skylights and doorways where applicable.
(k) Verification that the fireman's outfits are complete and in good condition.
(l) Verification that gas installations for domestic purposes comply with the relevant statutory requirements.

2.2.19 If a rig is fitted that is used for propulsion by wind force, then a general examination of the mast(s), standing rigging, sail/ wind propulsion system and associated structure and equipment is to be carried out. This examination maybe undertaken by a Surveyor and/or by a firm approved by LR.

2.2.20 For steel craft, the requirements of *Pt 1, Ch 3, 3.2 Intermediate Surveys 3.2.2* and *Pt 1, Ch 3, 5.4 Examination and testing - Additional items for steel craft 5.4.2* regarding the survey of water ballast spaces, integral sanitary tanks and bilges are also to be complied with as applicable.

■ *Section 3*
Intermediate Surveys - Hull and machinery requirements

3.1 General

3.1.1 Intermediate Surveys are to be held concurrently with statutory annual or other relevant statutory surveys wherever practicable.

3.2 Intermediate Surveys

3.2.1 The requirements of *Pt 1, Ch 3, 2 Annual Surveys - Hull and machinery requirements* are to be complied with so far as applicable.

3.2.2 For steel craft a general examination of salt water ballast tanks, integral sanitary tanks and bilges is to be carried out as required below. If such inspections reveal no visible structural defects then the examination may be limited to a verification that the protective coating remains in GOOD condition as defined in *Pt 1, Ch 3, 1.5 Definitions 1.5.7*. When considered necessary by the Surveyor thickness measurement of the structure is to be carried out. Where the protective coating is found to be other than in GOOD condition, and it has not been repaired, maintenance of class will be subject to the spaces in question being internally examined and gauged as necessary at Annual Surveys.

(a) For all craft over five years of age and up to 10 years of age, representative salt water ballast tanks, integral sanitary tanks and bilges are to be generally examined. Where the protective coating is found to be other than in GOOD condition, as defined in 1.5.6, or other defects are found, the examination is to be extended to other spaces of the same type.
(b) For steel craft over 10 years of age all salt water ballast tanks, integral sanitary tanks and bilges are to be generally examined.

3.2.3 For all craft over 10 years of age the anchors are to be partially lowered and raised using the windlass.

3.2.4 The electrical generating sets are to be examined under working conditions.

3.2.5 Representative internal spaces including fore and aft peak spaces, machinery spaces, bilges, etc are to be generally examined. These spaces should include all suspect areas, *see Pt 1, Ch 3, 1.5 Definitions 1.5.4*.

■ *Section 4*
Bottom Surveys – In Dry-Dock and In-Water Surveys - Hull and machinery requirements

4.1 General

4.1.1 At Bottom Surveys, the Surveyor is to examine the outside of the craft's bottom and associated appendages, including rudders, propellers and thrusters.

4.2 Bottom Surveys in Dry-Dock

4.2.1 Where a craft is in dry-dock or on a slipway it is to be placed on blocks of sufficient height and proper staging is to be erected as may be necessary, for the examination of the outside of the hull, rudder(s) and underwater fittings. The outside surface of the hull is to be cleaned as may be required by the Surveyor.

4.2.2 Attention is to be given to parts of the external hull structure particularly liable to structural deterioration from causes such as high stresses, chafing and lying on the ground, and to areas of structural discontinuity.

4.2.3 The following parts of the external hull structure are to be specially examined:

(a) For steel hulls attention is to be given to parts of the structure particularly liable to excessive corrosion and to any undue unfairness of the plating of the bottom. The coating system is to be examined and made good as necessary.
(b) For aluminium alloy hulls attention is to be given to areas adjacent to any bimetallic connections at skin fittings, etc.
(c) For composite hulls the gelcoat or other protective finish is to be examined for surface cracking, blistering or other damage which may impair the efficiency of the protection to the underlying laminate.

4.2.4 Where required by the Rules, the satisfactory condition of the cathodic protection is to be confirmed.

4.2.5 Visible parts of the rudder, rudder pintles, rudder stocks and couplings and stern frame are to be examined. The pintles are to be examined either by removal of the inspection plates, or if considered necessary by the Surveyor, the rudder is to be lifted to enable examination. The clearances in the rudder bearings and pintles are to be measured. The securing of rudder couplings and/or pintle fastenings is to be confirmed.

4.2.6 The sea chests, sea connections, scuppers and sanitary discharges, their attachments to the hull and the gratings at the sea inlets are to be examined.

4.2.7 Visible parts of the propeller(s) and sternbush(es), are to be examined. The clearance in the sternbush and the efficiency of the oil gland, if fitted, are to be ascertained and recorded. For controllable pitch propellers, the Surveyor is to be satisfied with the fastenings and tightness of hub and blade sealing.

4.2.8 The clearance of any shaft bracket bearings is to be ascertained.

4.2.9 The inboard shaft seals or glands are to be examined. Where flexible stern glands are fitted, the satisfactory condition of the rubber hose and securing clips is to be confirmed.

4.2.10 Special attention is to be given to the hull in way of underwater fittings such as transverse thrusters, stabilisers, etc.

4.2.11 Where applicable, attention is to be given to the connection and/or intersection of the cross-deck structure to the hulls of multi hull craft.

4.2.12 Visible parts of side thrusters are to be examined. Other propulsion systems which also have manoeuvring characteristics (such as directional propellers, vertical axis propellers, water jet units) are to be examined externally with focus on the condition of gear housing, propeller blades, bolt locking and other fastening arrangements. Sealing arrangements of propeller blades, propeller shaft and steering column are to be verified.

4.2.13 Where water jet units are fitted, the impeller, hull ducting, grating, nozzle steering and reversing arrangements are to be examined as far as is practicable.

4.2.14 Where transom mounted propulsion units are fitted, the steering arrangements and any flexible transom seals are to be examined.

4.2.15 When chain cables are ranged, the anchors and cables are to be examined by the Surveyor, *see also Pt 1, Ch 3, 5.3 Examination and testing – General 5.3.7*, and *Table 3.5.1 Survey preparation*.

4.2.16 For SES craft any flexible skirts together with their attachment are to be examined.

4.2.17 For hydrofoil or foil assisted craft the attachment of foils is to be examined.

4.2.18 To maintain an ***IWS** notation, at completion of each dry-docking the condition of the high resistance paint is to be confirmed, and, as applicable, satisfactory access arrangements to take the sternbush clearance and rudder pintle/bearing clearances are to be verified.

4.2.19 Where the anti-fouling system is changed completely, or partial repair is carried out affecting 25 per cent or more of the system, the coating specification and anti-fouling system is to be examined by the Surveyor in accordance with the *AFS - International Convention on the Control of Harmful Anti-Fouling Systems on Ships, 2001* and *Ch 15 Corrosion Prevention* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2021*.

4.3 In-Water Surveys

4.3.1 The Committee will accept an In-Water Survey at alternate Bottom Surveys on craft where an ***IWS** notation is assigned, *see Pt 1, Ch 2, 3.8 Other hull notations 3.8.2*.

4.3.2 The Committee may accept an In-water Survey at alternate Bottom Surveys on craft where suitable protection is applied to the underwater portion of the hull. If requested, an ***IWS** class notation may be assigned on satisfactory completion of the survey, provided that the applicable requirements of the Rules are complied with, *see also Pt 1, Ch 2, 3.8 Other hull notations 3.8.2*.

4.3.3 In-Water Survey is to provide the information normally obtained from the Bottom Survey in dry-dock. However, for oil lubricated sternbush arrangements, the clearance in the sternbush is not required to be ascertained subject to the Surveyor confirming satisfactory operating history and condition data records (lubricating oil analysis, bearing temperature, lubricating oil consumption) and verifying satisfactory operation of the screwshaft.

4.3.4 Proposals for In-Water Surveys are to be submitted in advance of the survey being required so that satisfactory arrangements can be agreed with LR.

4.3.5 The In-Water Survey is to be carried out at agreed geographical locations under the surveillance of a Surveyor to LR, with the craft in sheltered waters; the in-water visibility and the cleanliness of the hull below the waterline is to be clear enough to permit a meaningful examination which allows the Surveyor and diver to determine the condition of the plating, appendages and the welding. The Surveyor is to be satisfied with the methods of orientation of the divers on the plating, which should make use where necessary of permanent markings on the plating at selected points.

4.3.6 The In-Water Survey is to be carried out by a qualified diver employed by a firm approved by LR. In addition, for certain aspects of the In-Water Survey, consideration may be given to the use of a Remotely Operated Vehicle (ROV) operated by the LR approved firm.

4.3.7 The Surveyor is to be satisfied that the method of pictorial presentation is satisfactory. There is to be good two-way communication between the Surveyor and the diver.

4.3.8 If the In-Water Survey reveals damage or deterioration that requires early attention, the Surveyor may require that the craft be dry-docked in order that a fuller survey can be undertaken and the necessary work carried out.

■ *Section 5*
Special Survey - General - Hull requirements

5.1 General

5.1.1 The survey is to be of sufficient extent to ensure that the hull and related equipment is in satisfactory condition and is fit for its intended purpose, subject to proper maintenance and operation and to Periodical Surveys being carried out as required by the Regulations.

5.1.2 The requirements of *Pt 1, Ch 3, 2 Annual Surveys - Hull and machinery requirements* are to be complied with so far as applicable.

5.1.3 A Bottm Survey in accordance with the requirements of *Pt 1, Ch 3, 4 Bottom Surveys – In Dry-Dock and In-Water Surveys - Hull and machinery requirements* is to be carried out as part of the Special Survey.

5.1.4 For vessels assigned the **Laid-up** notation, an Underwater Examination (UWE) and general examination of hull and machinery is to be carried out in lieu of the normal Special Survey requirements.

5.2 Preparation

5.2.1 The craft is to be prepared for survey in accordance with the requirements of *Table 3.5.1 Survey preparation*. The preparation should be of sufficient extent to facilitate an examination to ascertain any excessive corrosion, erosion, deformation, fractures, damages and other structural deterioration.

Table 3.5.1 Survey preparation

Special Survey I (Craft 5 years old)	Special Survey II (Craft 10 years old)	Special Survey III (Craft 15 years old) and subsequent special surveys
(1) The interior of the craft is to be sufficiently opened out by the removal of lining, ceiling/cabin sole, portable tanks and ballast, etc. as required in order that the Surveyor may be satisfied as to the condition of suspect areas of the structure, *see Pt 1, Ch 3, 1.5 Definitions 1.5.4*. A record is to be made of those areas where lining, ceiling/cabin sole etc. were opened out and where equipment was removed during the survey. This record is to be retained for reference during subsequent surveys. (2) Machinery compartments, fore and aft peaks and other spaces as directed by the Surveyor, are to be cleared and cleaned as necessary, and the bilges and limbers all fore and aft are to be cleaned and prepared for examination. Platform plates in engine spaces are to be lifted as may be necessary, for the examination of the structure below. Where necessary, pipework may be required to be removed for examination of the structure. (3) In way of the single and/or double bottom areas, a sufficient amount of ceiling/cabin sole is to be lifted to permit examination of the bilges and/or tanktops below. (4) All integral tanks are to be cleaned as necessary to permit examination. (For steel craft *see Table 3.5.2 Tank internal examination requirements for steel craft*). (5) The masts and the sail/wind propulsion system are to be unshipped for survey. The whole of the standing rigging, including rigging screws, bolts, pins and fittings, is to be fully or partly disassembled as considered necessary by the Surveyor. **Note** This requirement may be waived at alternate Special Surveys or when the construction does not allow disassembly, provided that the masts and rigging are thoroughly examined *in situ*.	In addition to the requirements for Special Survey I, the following are to be complied with. (1) The chain locker is to be cleared and cleaned internally for examination of the structure and examination of the cable securing arrangements. The chain cables/anchor warps, as applicable, are to be ranged for inspection. The anchors are to be cleaned and placed in a accessible position for inspection. (2) The rudder is to be unshipped for examination of the rudder stock and trunk at the discretion of the Surveyor.	In addition to the requirements of Special Survey II the following are to be complied with. (1) Linings, ceiling/cabin soles, etc. are to be removed as required in order that the Surveyor may be satisfied as to the condition of the structure. For steel craft:- (2) Portions of wood sheathing, or other covering, on steel decks are to be removed, as considered necessary by the Surveyor, in order to ascertain the condition of the plating. (3) Where spaces are insulated, sufficient insulation is to be removed in each space to enable Surveyors to be satisfied with the condition of the structure. (4) Linings are to be removed in way of shell plating immediately above tank top connections to the side shell, in way of galleys/washrooms and beneath portlights and windows.
Note 'unshipped' means removed from its fixed or regular position and lay down, providing access for Close-up Survey. 'disassembled' means to dismantle and laying out all lines, tackles and other removable parts to the extent necessary to establish the condition of the rigging components.		

5.2.2 Where, in accordance with *Table 3.5.1 Survey preparation*, the craft is opened out by removal of linings, ceilings, cabin sole etc. and defects are found, further opening out will be required in order that the Surveyor can confirm the full extent of the defects.

5.3 Examination and testing – General

5.3.1 All spaces within the hull and superstructure including integral tanks are to be examined (*see also Pt 1, Ch 3, 5.4 Examination and testing - Additional items for steel craft 5.4.1* for tank examinations on steel craft). Special attention is to be paid to any suspect areas, *see Pt 1, Ch 3, 1.5 Definitions 1.5.4*.

5.3.2 Double bottom compartments, peak tanks and all other integral tanks are to be tested by a head sufficient to give the maximum pressure that can be experienced in service. Tanks may be tested afloat provided that their internal examination is also carried out afloat.

5.3.3 Where repairs are effected to the hull shell or bulkheads, any integral tanks in way are to be tested to the Surveyor's satisfaction on completion of these repairs.

5.3.4 All decks, casings and superstructures are to be examined.

5.3.5 The satisfactory attachment of any wood or other deck sheathing is to be confirmed, *see also Pt 1, Ch 3, 5.4 Examination and testing - Additional items for steel craft 5.4.4*.

5.3.6 Attention is to be given to the corners of openings and other discontinuities in the hull structure.

5.3.7 The anchors are to be examined. If the chain cables are ranged they are to be examined together with the chain locker, *see Table 3.5.1 Survey preparation*. If any length of chain cable is found to be reduced in mean diameter at its most worn part by 12 per cent or more from its nominal diameter, it is to be renewed. The windlass is to be examined.

5.3.8 The Surveyor is to be satisfied that there are suitable towlines and mooring ropes when these are a Rule requirement.

5.3.9 Rigs used for propulsion using wind force, associated structure and equipment, where fitted, are to be examined, *see Table 3.5.1 Survey preparation*. This examination may be undertaken by a Surveyor and/or by a firm approved by LR.

5.3.10 Representative structural fastenings, e.g. bolts in way of resiliently mounted deckhouses, are to be tested to ascertain their soundness and may require to be drawn for examination at the discretion of the Surveyor.

5.3.11 All watertight cable transits are to be examined to confirm their satisfactory condition by an LR Surveyor or by a firm approved as a service supplier in accordance with LR's *Procedures for Approval of Service Suppliers*. Where applicable, the electrical cables schedule of watertight penetrations (e.g. cable transit seal systems register) is to be reviewed to confirm it is being maintained, *see Pt 4, Ch 1, 4.5 Plans to be supplied to the unit* and *Pt 16, Ch 2, 11.11 Penetration of bulkheads and decks by cables*.

5.3.12 For craft to which *Pt 17, Ch 1 Fire Protection, Detection and Extinction – General* applies, the Surveyor is to be satisfied as to the efficient condition of the means of escape from crew and passenger spaces, and spaces in which crew are normally employed.

5.3.13 Ship side valves (i.e. sea connections, scuppers and sanitary discharges) are to be tested once reassembled.

5.3.14 At Special Survey III and subsequent special surveys, structural downflooding ducts and structural ventilation ducts are to be internally examined.

5.4 Examination and testing - Additional items for steel craft

5.4.1 All integral tanks are generally to be internally examined. However, in certain circumstances the internal examination of lubricating oil, fresh water and fuel oil tanks may be waived. For the minimum extent of tank internal examination, *see Table 3.5.2 Tank internal examination requirements for steel craft*.

Table 3.5.2 Tank internal examination requirements for steel craft

Tank	Special Survey I (Craft 5 years old)	Special Survey II (Craft 10 years old)	Special Survey III (Craft 15 years old)	Special Survey IV (Craft 20 years old)	All Subsequent Special Surveys
Peaks	All tanks	All tanks	All tanks	All tanks	All tanks
Salt water ballast	All tanks	All tanks	All tanks	All tanks	All tanks
Lubricating oil	None	None	*See* Note 2	*See* Note 3	All tanks
Fresh water	None	*See* Note 1	*See* Note 2	*See* Note 3	All tanks
Fuel oil	None	*See* Note 1	*See* Note 2	*See* Note 3	All tanks

Sanitary	All tanks	All tanks	All tanks	All tanks	All tanks
Note 1. Tanks (excluding peak tanks) used exclusively for fuel oil or fresh water need not all be examined internally provided that the Surveyor is satisfied with the condition, after both external examination and testing and from an internal examination of the after end of one forward double bottom tank, and of one selected deep tank.					
Note 2. Tanks (excluding peak tanks) used exclusively for fuel oil, fuel oil and fresh water ballast, or lubricating oil, need not all be examined internally provided that the Surveyor is satisfied with the condition, after both external examination and testing and from an internal examination of one double bottom tank forward and one aft and one deep tank.					
Note 3. Tanks (excluding peak tanks) used exclusively for fuel oil, fuel oil and fresh water ballast, or lubricating oil, need not all be examined internally provided that the Surveyor is satisfied with the condition, after both external examination and testing and from internal examination of one double bottom tank amidships, one forward and one aft and one deep tank.					
Note 4. When examining tanks internally the Surveyor is to verify that striking plates or other additional reinforcement is fitted under sounding pipes. In the case of tanks fitted only with remote gauging facilities, the satisfactory operation of the gauges is to be confirmed.					

5.4.2 In salt water ballast spaces, integral sanitary tanks and bilges where the protective coating is found to be other than in GOOD condition as defined in *Pt 1, Ch 3, 1.5 Definitions 1.5.7* and it has not been repaired, maintenance of class will be subject to the spaces in question being internally examined and gauged as necessary at Annual Surveys.

5.4.3 The protection of steelwork, other than as referred to in 5.4.2 should be examined and made good where necessary on satisfactory completion of the survey. In areas where the inner surface of the bottom plating is covered with cement, asphalt or other composition, the removal of this covering may be dispensed with, provided that it is found sound and adhering satisfactorily to the steel.

5.4.4 Wood deck sheathing is to be examined and the caulking is to be tested and recaulked as necessary. If decay or rot is found, or the wood is excessively worn, the wood is to be renewed. Attention is to be given to the condition of the plating under wood deck sheathing or other deck covering. If it is found that such coverings are broken, or are not adhering closely to the plating, sections are to be removed as necessary to ascertain the condition of the plating. *See also Pt 1, Ch 3, 1.2 Surveys for damage or alterations 1.2.1*.

5.4.5 The structure in way of bimetallic connections e.g. to aluminium alloy deckhouses is to be examined.

5.4.6 The Surveyors may require to measure the thickness of the material in any portion of the structure where signs of wastage are evident or wastage is normally found. Any parts of the structure which are found defective or excessively reduced in scantlings are to be made good by materials of the approved scantlings and quality. The minimum requirements for thickness measurements are given in *Pt 1, Ch 3, 6 Special Survey - Thickness measurement requirements for steel craft*.

5.5 Examination and testing - Additional items for aluminium alloy craft

5.5.1 The structure in way of any bimetallic connections is to be examined and the efficiency of the insulation arrangements confirmed.

5.5.2 The Surveyor may require to measure the thickness of the material in any portion of the structure where signs of deterioration are evident or may normally be found. Any parts of the structure which are found defective or excessively reduced in scantlings are to be made good by materials of the approved scantlings and quality.

5.6 Examination and testing - Additional items for composite craft

5.6.1 The bonded attachments of frames, floors, bulkheads, structural joinery, engine bearers, sterntubes, rudder tubes, and integral tank boundaries are to be examined.

5.6.2 The hull to deck joint together with any joints between the deck and deckhouses or superstructures are to be examined.

5.6.3 The structure in way of the bolted attachment of fittings including guardrail stanchions, windlass, shaft brackets, fendering, mooring bitts, etc. is to be examined.

Section 6
Special Survey - Thickness measurement requirements for steel craft

6.1 General

6.1.1 Thickness measurements, as required by *Pt 1, Ch 3, 5 Special Survey - General - Hull requirements* are to be carried out in accordance with the following requirements.

6.1.2 Thickness measurements are to be taken at the forward and aft areas of all plates. In all cases the measurements are to represent the average of the multiple measurements taken on each plate. The extent of local substantial corrosion of plates is to be established by intensive measurement in the affected areas. Where measured plates are renewed, the thicknesses of adjacent plates in the same strake are to be reported.

6.1.3 Thickness measurements are normally to be taken by means of ultrasonic test equipment. For vessels less than 500 gross tons and all fishing vessels, a suitably qualified exclusive Surveyor (where available) may carry out thickness measurements. On all other occasions, thickness measurements are to be carried out by a firm approved in accordance with LR's *Approval for Thickness Measurement of Hull Structures*.

6.1.4 Thickness measurements may be carried out in association with the fourth Annual Survey.

6.1.5 The minimum requirements for thickness measurement are indicated in *Table 3.6.1 Thickness measurement of steel craft*.

6.1.6 The Surveyor may extend the scope of thickness measurement if deemed necessary.

6.1.7 The acceptance criteria for thickness measurements are according to the LR document *Thickness Measurement and Close-Up Survey Guidance.*

Table 3.6.1 Thickness measurement of steel craft

Special Survey I (Craft 5 years old)	Special Survey II (Craft 10 years old)	Special Survey III (Craft 15 years old) (Craft 20 years old and over)	Special Survey IV and subsequent
Suspect areas, as required by the Surveyor and may include areas where the coatings are found to be other than in GOOD condition,*see* note 1.	Suspect areas, as required by the Surveyor and may include areas where the coatings are found to be other than in GOOD condition, *see* note 1.	(1) Any exposed plating throughout the Main Deck. (2) Shell plating in way of the waterline throughout the length of the craft. (3) Suspect areas, as required by the Surveyor and may include areas where the coatings are found to be other than in GOOD condition,*see* note 1.	(1) All Main Deck plating outside deckhouses or superstructures and including plating in way of wood deck planking or sheathing. (2) Shell plating in way of, and below, the waterline throughout the length of the craft. (3) 2 transverse sections of deck and shell plating within 0.5*L* amidships. (4) Suspect areas, as required by the Surveyor and to include as applicable:- (a) Areas where the coatings are found to be other than in GOOD condition. (b) Shell and tanktop plating immediately adjacent to tank top margins.

			(c) Bottom shell in way of any cement, asphalt or other composition. (d) Shell plating below portlights and windows. (e) Tanktop plating below ceiling or cabin soles. (f) Deck plating and side shell plating in way of galleys, washrooms and refrigerated store spaces. (g) Structure in way of integral sanitary tanks.
Note 1. Suspect areas are locations within the hull structure vulnerable to increased likelihood of structural deterioration and may include, for steel hulls, areas of substantial corrosion and/or fatigue cracking, *see also Pt 1, Ch 3, 1.5 Definitions 1.5.4* and *Pt 1, Ch 3, 5.4 Examination and testing - Additional items for steel craft 5.4.6*. Note 2. Coating condition for steel craft is defined in *Pt 1, Ch 3, 1.5 Definitions 1.5.7*.			

6.2 Thickness measurement reporting

6.2.1 A report is to be prepared by the approved firm carrying out the thickness measurement. The report is to give the location of measurement, the thickness measured as well as the corresponding original thickness. The report is to give the date when the measurement was carried out, the type of measuring equipment, names of personnel and their qualifications and is to be signed by the operator and supervisor.

6.2.2 The thickness measurement report is to be verified and signed by the Surveyor.

■ *Section 7* Machinery surveys - General requirements

7.1 Annual, Intermediate and Bottom Surveys

7.1.1 For Annual, Intermediate and Bottom Surveys, *see* Sections *Pt 1, Ch 3, 2 Annual Surveys - Hull and machinery requirements*, *Pt 1, Ch 3, 3 Intermediate Surveys - Hull and machinery requirements* and *Pt 1, Ch 3, 4 Bottom Surveys – In Dry-Dock and In-Water Surveys - Hull and machinery requirements* .

7.1.2 For craft where an Approved Planned Maintenance Scheme is in operation an Annual Survey of the machinery is to be carried out together with an audit of the maintenance and monitoring records.

7.1.3 For vessels assigned the **Laid-up** notation, a general examination of the machinery is to be carried out in lieu of the normal Annual Survey/Intermediate Survey requirements.

7.2 Complete Surveys

7.2.1 While the craft is in dry-dock, all openings to the sea in the machinery spaces and pump-rooms, together with the valves, cocks and the fastenings with which these are connected to the hull, are to be examined.

7.2.2 Athwartships thrust propellers are to be generally examined so far as is possible in dry dock and tested under working conditions afloat for satisfactory operation.

7.2.3 All shafts (except screwshafts and tube shafts, for which special arrangements are detailed in *Pt 1, Ch 3, 12 Screwshafts, tube shafts, propellers and water jet units*), thrust block and all bearings are to be examined. The lower halves of bearings need not be exposed if alignment and wear are found to be acceptable.

7.2.4 An examination is to be made as far as practicable of all propulsion gears complete with all wheels, pinions, shafts, bearings and gear teeth, thrust bearings and incorporated clutch arrangements.

7.2.5 The following auxiliaries and components are also to be examined:

(a) Auxiliary engines, auxiliary air compressors with their intercoolers, filters and/or oil separators and safety devices, and all pumps and components used for essential services.
(b) Steering machinery.
(c) Windlass and associated driving equipment, where fitted.
(d) The holding down bolts, chocks or resilient mounts of main and auxiliary engines, gearcases, thrust blocks and intermediate shaft bearings.
(e) Where Thrusters and/or Podded Propulsors are fitted and have been assigned the ShipRight descriptive note **ThCM**, the degree of inspection required whilst in dock will be determined by the analysis of Condition Monitoring records. Refer to ShipRight Procedure *Machinery Planned Maintenance and Condition Monitoring*, Section 8.

7.2.6 All air receivers for essential services, together with their mountings, valves and safety devices, are to be cleaned internally and examined internally and externally. If internal examination of the air receivers is not practicable, they are to be tested hydraulically to 1,3 times the working pressure.

7.2.7 The valves, cocks and strainers of the bilge system including bilge injection, are to be opened up as considered necessary by the Surveyor and together with pipes, are to be examined and tested under working conditions. The fuel oil, feed, lubricating oil and cooling water systems also any ballast connections together with all pressure filters, heaters and coolers used for essential services, are to be opened up and examined or tested, as considered necessary by the Surveyor. All safety devices for the foregoing items are to be examined.

7.2.8 Fuel tanks which do not form part of the craft's structure are to be examined, and if considered necessary by the Surveyor, they are to be tested to the pressure specified for new tanks. The tanks need not be examined internally at the first survey if they are found satisfactory on external inspection. The mountings, fittings and remote controls of all fuel oil tanks are to be examined, so far as is practicable.

7.2.9 Where remote and/or automatic controls are fitted for essential machinery, they are to be tested to demonstrate that they are in good working order.

7.2.10 In addition to the above, detailed requirements for gas turbines, reciprocating internal combustion engines and electrical installations are given in *Pt 1, Ch 3, 8 Gas turbines - Detailed requirements*, *Pt 1, Ch 3, 9 Reciprocating internal combustion engines - Detailed requirements* and *Pt 1, Ch 3, 10 Electrical equipment* respectively. In certain instances, upon application by the Owner or where indicated by the manufacturer's servicing recommendations, the Committee will give consideration to the circumstances where deviation from these detailed requirements is warranted, taking account of design, appropriate indicating equipment (e.g. vibration indicators) and operational records (*see Pt 1, Ch 2, 4.5 Existing service craft and yachts - Periodical Surveys 4.5.21* and *Pt 1, Ch 2, 4.5 Existing service craft and yachts - Periodical Surveys 4.5.27*).

■ *Section 8*
Gas turbines - Detailed requirements

8.1 Complete Surveys

8.1.1 The requirements of *Pt 1, Ch 3, 7 Machinery surveys - General requirements* are to be complied with. *See Pt 1, Ch 3, 7.2 Complete Surveys 7.2.10* regarding any deviation from the following.

8.1.2 The following parts are to be opened out and examined:

- Compressor including impellers or blading, rotors and casing.
- Combustion chambers, burners, intercoolers and heat exchangers.
- Gas, air and fuel piping and fittings.
- Gas generator turbine and power turbine blading, rotors and casing.
- Rotors to include couplings, clutches, bearings and tie bolts.
- Auxiliary mounted fuel, L.O. and cooling water pumps, their drive transmissions and fittings.
- Starting system (for starting air pipes, *see Pt 1, Ch 3, 9.2 Complete Surveys 9.2.3*).

- All safety devices and local controls.
- Mountings and support frame.

8.1.3 The compressor/turbine units are to be operated and maintained in accordance with the manufacturer's instructions. Overhauls, including the prescribed replacement of limited life components, are to be undertaken at the specified intervals. Full service records are to be available for review by the Surveyor.

8.1.4 The manoeuvring of the propulsion system is to be tested under working conditions.

■ *Section 9* Reciprocating internal combustion engines - Detailed requirements

9.1 Scope

9.1.1 The requirements of this Section are applicable to reciprocating internal combustion engines operating on liquid, gas or dual fuel, providing power for services essential to the safety of the vessel.

9.2 Complete Surveys

9.2.1 The requirements of *Pt 1, Ch 3, 7 Machinery surveys - General requirements* are to be complied with. *See Pt 1, Ch 3, 7.2 Complete Surveys 7.2.10* regarding any deviation from the following.

9.2.2 The following parts are to be opened out and examined:

- Cylinders and covers.
- Valves and valve gear.
- Pistons and connecting rods.
- Crankshafts and all bearings.
- Crankcases and entablatures.
- Crankcase door fastenings and explosion relief devices.
- Turbochargers and their associated coolers.
- Air compressors and their intercoolers.
- Filters and/or separators and safety devices.
- Fuel pumps and fittings.
- Camshaft drives and balancer units.
- Vibration dampers or detuners.
- Flexible couplings and clutches.
- Reverse gears.
- Attached pumps and cooling arrangements.

9.2.3 Selected pipes in the starting air system, if fitted, are to be removed for internal examination and are to be hammer tested. If any appreciable amount of lubricating oil is found in the pipes, the starting air system is to be thoroughly cleaned internally by steaming out, or other suitable means. Some of the pipes selected are to be those adjacent to the starting air valves at the cylinders and to the discharges from the air compressors.

9.2.4 The electric ignition system, if fitted, is to be examined and tested.

9.2.5 The manoeuvring of engines is to be tested under working conditions. Initial starting arrangements are to be tested.

Section 10
Electrical equipment

10.1 Annual and Intermediate Surveys

10.1.1 The electrical contacts of air circuit-breakers are to be visually inspected and maintained in accordance with the manufacturer's recommendations by suitably qualified and trained personnel. Appropriate maintenance records are to be made available to the attending Surveyor on request.

10.1.2 Where the craft is fitted with harmonic filters, the harmonic distortion level is to be measured annually and after any modification to the craft electrical distribution system or associated consumers. As a minimum, harmonic distortion measurements are to be taken at the main busbar under seagoing conditions, as close to the annual survey as possible, and readings are to be recorded when the greatest amount of distortion is indicated, by suitably qualified and trained personnel.

Records are to include which equipment was running and the filters that were in service, and these records are to be made available to the attending Surveyor on request.

10.1.3 The requirements of *Pt 1, Ch 3, 2.2 Annual Surveys 2.2.15* and *Pt 1, Ch 3, 3.2 Intermediate Surveys 3.2.4* are to be complied with as far as applicable.

10.2 Complete Surveys

10.2.1 An electrical insulation resistance test is to be made on the electrical equipment and cables. The installation may be sub-divided, or equipment which may be damaged disconnected, for the purpose of this test.

10.2.2 The fittings on the main and emergency switchboards, section boards and distribution boards are to be examined and over-current protective devices and fuses inspected to verify that they provide suitable protection for their respective circuits.

10.2.3 Generator circuit-breakers are to be tested, so far as is practicable, to verify that protective devices including preference tripping relays, if fitted, operate satisfactorily.

10.2.4 Air circuit-breakers for essential or emergency services and rated at 800 A and above are to be surveyed to ensure that the manufacturer's recommended number of switching options has not been exceeded. *See* Vol 7, *Pt 16, Ch 2, 7.3 Circuit-breakers 7.3.6*. Where a breaker is not fitted with an automatic counter, a written record is to be kept.

10.2.5 The electric cables and their securing arrangements are to be examined, so far as is practicable, without undue disturbance of fixtures or casings unless opening up is considered necessary as a result of observation or of the tests required by *Pt 1, Ch 3, 10.2 Complete Surveys 10.2.1*.

10.2.6 The generator prime movers are to be surveyed as required by *Pt 1, Ch 3, 8 Gas turbines - Detailed requirements* and *Pt 1, Ch 3, 9 Reciprocating internal combustion engines - Detailed requirements* and the governing of the engines tested. The motors concerned with essential services together with associated control and switch gear are to be examined and if considered necessary, are to be operated, so far as is practicable, under working conditions. All generators and steering gear motors are to be examined and are to be operated under working conditions, though not necessarily under full load or simultaneously.

10.2.7 Where transformers or electrical apparatus associated with supplies to essential services are liquid-immersed, the Owner is to arrange for samples of the liquid to be taken and tested for dissolved gases, breakdown voltage, acidity and moisture by a competent authority, in accordance with the equipment manufacturer's requirements, and a certificate giving the test results is to be made available to the Surveyor on request.

10.2.8 Navigation light indicators are to be tried under working conditions, and correct operation on the failure of supply or failure of navigation lights verified.

10.2.9 The emergency sources of electrical power, where fitted, together with their automatic arrangements and associated circuits are to be tested.

10.2.10 Emergency lighting, transitional emergency lighting, supplementary emergency lighting, general emergency alarm and public address systems are to be tested as far as practicable.

10.2.11 Where the craft is electrically propelled, the propulsion motors, generators, propulsion transformers, propulsion conversion equipment, cables, harmonic filters, neutral earthing resistors, dynamic braking resistors and all ancillary electrical equipment that forms part of the propulsion drive and control system, exciters and ventilating plant (including coolers) associated therewith are to be surveyed, and the insulation resistance to earth is to be tested. Special attention is to be given to windings,

commutators and slip-rings. Where practicable, the low voltage and high voltage windings of resin cast propulsion transformers are to be subjected to boroscopic inspection, to assess the physical condition of their insulation and for signs of mechanical and thermal damage. The operation of protective gear and alarm devices is to be checked, so far as is practicable. Insulating oil, if used, is to be tested in accordance with *Pt 1, Ch 3, 10.2 Complete Surveys 10.2.7*. Interlocks intended to prevent unsafe operations or unauthorised access are to be checked to verify that they are functioning correctly. Emergency overspeed governors are to be tested.

10.2.12 Where batteries provide the source of power for any essential services, their installation, including charging and ventilation arrangements, is to be examined.

■ *Section 11* Screwshafts, tube shafts, propellers and water jet units

11.1 Applicability

11.1.1 The requirements of this Section are applicable as follows:

(a) to craft delivered on or after 1 January 2016; and
(b) after the first screwshaft survey scheduled on or after 1 January 2016 for craft delivered before 1 January 2016.

11.1.2 For craft delivered before 1 January 2016, the first screwshaft survey held on or after 1 January 2016 is to be held in accordance with the requirements of *Pt 1, Ch 3, 12 Screwshafts, tube shafts, propellers and water jet units*.

11.2 Definitions

11.2.1 **Adequate means for protection against corrosion**. An adequate means for protection against corrosion is an approved means for full protection of the shaft against sea water intrusion and subsequent corrosion attack. Such means are used for the protection of common steel material against corrosion particularly in combination with water lubricated bearings. Typical means are to be for example:

(a) continuous metallic, corrosion-resistant liners (*Pt 11, Ch 2, 4.14 Corrosion resistant liners on shafts*)
(b) continuous cladding,
(c) multiple layer synthetic coating,
(d) multiple layers of fiberglass,
(e) combinations of above mentioned,
(f) rubber/elastomer covering coating.

The means for protection against corrosion are to be installed/applied according to LR approved procedures.

11.2.2 **Fresh Water sample test**. At the Screwshaft Survey, a sample of the fresh water in a closed loop fresh water lubricated shaft is to be taken in the presence of a Surveyor. The requirements for Fresh Water sample tests are given in the ShipRight Procedure Machinery Planned Maintenance and Condition Monitoring.

11.2.3 **Lubricating oil analysis**. Lubricating oil analysis is to be carried out at regular intervals not exceeding six months. The documentation on lubricating oil analysis is to be available on board. Oil samples, to be submitted for the analysis, should be taken under service conditions.

11.2.4 **Oil sample examination**. An oil sample examination is a visual examination of the sterntube lubricating oil taken in the presence of a Surveyor, with a focus on water contamination.

11.2.5 **Service records**. Service records are regularly recorded data showing in-service conditions of the shaft(s) and are to include:

(a) For Oil Lubricated Stern Bearings: lubricating oil temperature, bearing temperature and oil consumption records.
(b) For Closed Loop System Fresh Water Lubricated Bearings: water flow, water temperature, salinity, pH, make-up water and water pressure (depending on design).

11.2.6 **Survey Methods on Closed Systems**. Oil Lubricated Shafts or Closed Loop System Fresh Water Lubricated Shafts:

(a) **TS Method 1** – Survey of screwshaft, tube shaft and propeller in accordance with the requirements of TS Method 1, *see Table 3.11.3 Shaft Survey Methods*. Primarily the shaft is withdrawn and the propeller is removed.

(b) **TS Method 2** – Survey of screwshaft, tube shaft and propeller in accordance with the requirements of TS Method 2, *see Table 3.11.3 Shaft Survey Methods* Shaft survey methods. Primarily records are reviewed, the propeller is removed but the shaft is not withdrawn.

(c) **TS Method 3** – Survey of screwshaft, tube shaft and propeller in accordance with the requirements of TS Method 3, *see Table 3.11.3 Shaft Survey Methods*. Primarily records are reviewed, the shaft is not withdrawn and the propeller is not removed.

11.2.7 **Survey Methods on Open Systems**. Water Lubricated Shafts:

(a) **TS Method 4** – Survey of screwshaft, tubeshaft and propeller in accordance with the requirements of TS Method 4, *see Table 3.11.3 Shaft Survey Methods*. Primarily the shaft is withdrawn and the propeller is removed.

11.2.8 **Tube shaft** is a shaft placed between the intermediate shaft and propeller shaft, normally arranged within a sterntube or running in open water. It may also be called a Sterntube Shaft.

11.3 Closed Systems – Oil Lubricated Shafts or Closed Loop System Fresh Water Lubricated Shafts: Frequency of surveys

11.3.1 Oil lubricated shafts fitted with approved oil glands and closed loop system fresh water lubricated shafts fitted with approved adequate means of protection against corrosion or fabricated from corrosion-resistant material are to be surveyed in accordance with *Pt 1, Ch 3, 11.3 Closed Systems – Oil Lubricated Shafts or Closed Loop System Fresh Water Lubricated Shafts: Frequency of surveys 11.3.3* to *Pt 1, Ch 3, 11.3 Closed Systems – Oil Lubricated Shafts or Closed Loop System Fresh Water Lubricated Shafts: Frequency of surveys 11.3.5*.

11.3.2 Shafts with a keyless propeller connection or a flanged propeller connection (including controllable pitch propellers for main propulsion purposes) are to be surveyed at intervals of five years in accordance with TS Method 1, 2 or 3.

11.3.3 Shafts with a keyed propeller connection with a keyway that complies fully with the present Rules are to be surveyed at intervals of five years in accordance with TS Method 1 or 2; TS Method 3 is not permitted.

11.3.4 For oil lubricated keyless shafts, the maximum interval between two surveys carried out according to TS Method 1 or TS Method 2 shall not exceed 15 years, except in the case when one extension for no more than three months is agreed.

11.3.5 Closed loop system fresh water lubricated shafts may be surveyed in accordance with TS Method 2 or for keyless shafts TS Method 3, only if the descriptive note **ShipRight SCM** is assigned. Notwithstanding this, the maximum interval between two surveys carried out according to TS Method 1 shall not exceed 15 years, except in the case when one extension for no more than three months is agreed.

11.3.6 Shaft configurations other than those listed in *Pt 1, Ch 3, 11.3 Closed Systems – Oil Lubricated Shafts or Closed Loop System Fresh Water Lubricated Shafts: Frequency of surveys 11.3.1* to *Pt 1, Ch 3, 11.3 Closed Systems – Oil Lubricated Shafts or Closed Loop System Fresh Water Lubricated Shafts: Frequency of surveys 11.3.5* above are to be surveyed at intervals of three years in accordance with TS Method 1.

11.3.7 TS Method 2 and TS Method 3 are only permitted where the prerequisite service records and data specified for those methods are to be provided. If at the time of survey the attending Surveyor is not satisfied with the service records and data presented, then the shaft may be required to be withdrawn. The service records and data are to be retained on board and audited by LR at the Annual Survey.

11.3.8 For oil lubricated arrangements, the descriptive note **ShipRight SCM** is not a prerequisite in order to hold TS Method 2 and TS Method 3.

11.3.9 In order to assign and maintain the descriptive note **ShipRight SCM,** the requirements of *Pt 11, Ch 2, 5.2 Screwshaft Condition Monitoring (SCM)* and *ShipRight Procedure Machinery Planned Maintenance and Condition Monitoring, Section 6* are to be complied with, including the requirements therein for onboard maintenance of records and review of them by the attending Surveyor at Annual Survey.

11.3.10 For surveys completed within three months before the shaft survey due date, the next period will start from the shaft survey due date.

11.3.11 *See* Summary of Survey Intervals and Extensions for closed systems in *Table 3.11.1 Summary of Survey Intervals and Extensions – Closed systems*

11.4 Open Systems – Water Lubricated Shafts: Frequency of surveys

11.4.1 Survey in accordance with TS Method 4 at intervals of five years is applicable to any of the following:

(a) Single shaft operating in fresh water only;
(b) Single shaft provided with approved adequate means of protection against corrosion or fabricated from corrosion-resistant material;
(c) Multiple shaft arrangements.

11.4.2 Single shaft configurations other than listed above are to be surveyed every three years in accordance with TS Method 4.

11.4.3 For shafts subject to five-yearly surveys with keyless connections, at the Surveyor's discretion removal of the propeller and NDE of the shaft taper, as required by TS Method 4, need only be carried out every 15 years, subject to a satisfactory visual inspection of all accessible parts of the shafting system at the intervening surveys.

11.4.4 For surveys completed within three months before the shaft survey due date, the next survey period will start from the shaft survey due date.

11.4.5 At the discretion of the Classification Committee, consideration may be given to accept special arrangements to monitor the condition of the screwshaft, bearings, sealing devices and the sterntube lubricant system so as to allow an extension to the interval between withdrawals of the Screwshaft required by TS Method 4. This is subject to the shaft being provided with approved adequate means of protection against corrosion or being fabricated from corrosion-resistant material.

11.4.6 *See* Summary of Survey Intervals and Extensions for open systems in *Table 3.11.2 Summary of Survey Intervals and Extensions – Open systems*.

11.5 Survey extensions

11.5.1 For all types of propeller connections, consideration can be given at the discretion of the Classification Committee to an extension of the interval between two consecutive surveys after the execution of an extension survey as follows:

(a) Extension up to a maximum of two and a half years: Only permitted for closed systems. No more than one extension can be considered. No further extension, of other type, can be considered.
(b) Extension up to a maximum of one year: Two consecutive 'one year extensions' can be considered. Where an additional extension is agreed the requirements of the 'two and a half year extension' are to be carried out and the shaft survey due date, prior to the previous extension(s), is extended for a maximum of two and a half years.
(c) Extension up to a maximum of three months: One 'three month extension' can be considered. In the event an additional extension is agreed the requirements of the 'one year extension' or 'two and a half years extension' are to be carried out and the shaft survey due date, prior to the previous extension, is extended for a maximum of one year or two and a half years.

11.5.2 If the extension survey is carried out within one month of the shaft survey due date then the extension will take effect from the shaft survey due date.

11.5.3 If the extension survey is carried out more than one month prior to the shaft survey due date, then the period of extension will take effect from the date on which the extension survey was completed.

Table 3.11.1 Summary of Survey Intervals and Extensions – Closed systems

Oil Lubricated			
	Flanged Propeller Coupling	Keyless Propeller Coupling	Keyed Propeller Coupling (*see* Note b)
Every 5 years (*see* Note a)	TS Method 1 or TS Method 2 or TS Method 3	TS Method 1 or TS Method 2 or TS Method 3 (*see* Note c)	TS Method 1 or TS Method 2
Extension 2,5 years	Yes (*see* Note d)	Yes (*see* Note d)	Yes (*see* Note d)
Extension 1 year	Yes (*see* Note e)	Yes (*see* Note e)	Yes (*see* Note e)
Extension 3 months	Yes (*see* Note f)	Yes (*see* Note f)	Yes (*see* Note f)
Closed Loop System Fresh Water Lubricated			

	Flanged Propeller Coupling	Keyless Propeller Coupling	Keyed Propeller Coupling (*see* Note b)
Every 5 years (*see* Note a)	TS Method 1 (*see* Note g) or TS Method 2 or TS Method 3	TS Method 1 (*see* Note g) or TS Method 2 or TS Method 3	TS Method 1 (*see* Note g) or TS Method 2
Extension 2,5 years	Yes (*see* Note d)	Yes (*see* Note d)	Yes (*see* Note d)
Extension 1 year	Yes (*see* Note e)	Yes (*see* Note e)	Yes (*see* Note e)
Extension 3 months	Yes (*see* Note f)	Yes (*see* Note f)	Yes (*see* Note f)

General notes:

For surveys (TS Method 1, or TS Method 2, or TS Method 3) completed within 3 months before the shaft survey due date, the next period will start from the shaft survey due date.

If the extension survey is carried out within 1 month of the shaft survey due date then the extension will take effect from the shaft survey due date. If the extension survey is carried out more than 1 month prior to the shaft survey due date, then the period of extension counts from the date when the extension survey was completed.

Notes:

Note a. Unless an Extension (Extension 2,5 years, Extension 1 year, Extension 3 months) is applied in between.

Note b. TS Method 3 not allowed.

Note c. The maximum interval between two surveys carried out according to TS Method 1 or TS Method 2 shall not exceed 15 years, except in the case when one extension for no more than 3 months is agreed.

Note d. No more than one extension can be considered. No further extension of other type can be considered.

Note e. Two consecutive extensions can be considered. Where an additional extension is agreed the requirements of the ‘2,5 year extension’ are to be carried out and the shaft survey due date, prior to the previous extension(s), is extended for a maximum of 2,5 years.

Note f. Extension up to a maximum of 3 months: One ‘3 month extension’ can be considered. In the event an additional extension is agreed the requirements of the ‘1 year extension’ or ‘2,5 years extension’ are to be carried out and the shaft survey due date, prior to the previous extension, is extended for a maximum of 1 year or 2,5 years.

Note g. The maximum interval between two surveys carried out according to TS Method 1 shall not be more than 15 years, except in the case when one extension for no more than 3 months is agreed.

Table 3.11.2 Summary of Survey Intervals and Extensions – Open systems

• Single shaft operating exclusively in fresh water. • Single shaft provided with adequate means of corrosion protection, single corrosion resistant shaft. • All kinds of multiple shaft arrangements.		Other shaft configuration.	
	All kinds of Propeller Coupling (*see* Note d)		All kinds of Propeller Coupling (*see* Note d)
Every 5 years (*see* Note a)	TS Method 4	Every 3 years (*see* Note a)	TS Method 4
Extension 1 year	Yes (*see* Note b)	Extension 1 year	Yes (*see* Note b)
Extension 3 months	Yes (*see* Note c)	Extension 3 months	Yes (*see* Note c)

General notes:
For surveys (TS Method 4) completed within 3 months before the shaft survey due date, the next period will start from the shaft survey due date.
If the extension survey is carried out within 1 month of the shaft survey due date then the extension will take effect from the shaft survey due date. If the extension survey is carried out more than 1 month prior to the shaft survey due date, then the period of extension counts from the date when the extension survey was completed.
Notes:
Note a. Unless an Extension (Extension 1 year, Extension 3 months) is applied in between.
Note b. No more than one extension can be considered. No further extension, of other type, can be considered.
Note c. One extension can be considered. In the event an additional extension is agreed the requirements of the one year extension are to be carried out and the shaft survey due date prior to the previous extension is extended for a maximum of one year.
Note d. For keyless propeller connections the maximum interval between two consecutive dismantling and verifications of the shaft cone by means of non-destructive examination (NDE) shall not exceed 15 years.

11.6 Shaft Survey Methods

11.6.1 For the survey methods *see Table 3.11.3 Shaft Survey Methods* below.

Table 3.11.3 Shaft Survey Methods

	TS METHOD 1	TS METHOD 2	TS METHOD 3	TS METHOD 4
GENERAL				
Drawing the shaft and examining the entire shaft (including liners, corrosion protection system and stress reducing features, where provided), sealing system and bearings	X			X
SHAFT				
Visual examination of all accessible parts of the shafting system *in situ*		X	X	
For keyed and keyless propeller connections, removing the propeller to expose the forward end of the taper	X	X		X
For keyed and keyless propeller connections, perform a non-destructive examination (NDE) by an approved surface crack-detection method around the after end of the cylindrical part of the shaft and the forward one-third of the shaft cone, including the keyway with the key removed (if fitted); for shafts provided with liners the NDE shall be extended to the after edge of the liner	X	X		X
For flanged connections, whenever the coupling bolts of any type of flange-connected shaft are removed or the flange radius is made accessible in connection with overhaul, repairs or when deemed necessary by the Surveyor, the coupling bolts and flange radius are to be examined by means of an approved surface crack detection method	X	X	X	X
Visual examination of all accessible parts of the shafting system following re-installation of the shaft	X			X
PROPELLER				
Examination of the propeller	X	X	X	X
Controllable pitch propellers, where fitted, are to be opened up and the working parts examined, together with the control gear. Propeller to be examined upon reassembly	X	X		X

Where a controllable pitch propeller is fitted, at least one of the blades is to be dismantled completely for examination of the working parts and the control gear. Propeller to be examined upon reassembly			X	
Examination of the propeller following re-installation	X	X		X
BEARING CLEARANCES				
Checking, recording and verification of bearing clearances	X			X
Recording the bearing weardown measurements after re-installation, if applicable	X			
Checking and recording the bearing weardown measurements		X	X	
SEALING SYSTEM				
Examine the inboard and outboard seals with shaft removed and following the re-installation of the shaft and propeller	X			X
Examine the inboard and outboard seals		X	X	
Examination of seal liner		X	X	
OTHERS				
Stationary supporting structure and any erosion protection inserts or doublers are to be examined in way of any propulsion devices	X	X	X	X
Verification of no unapproved repairs by grinding or welding of shaft and/or propeller	X	X	X	X
SERVICE RECORDS				
Review of service records		X	X	
Review of test records of Lubricating Oil Analysis (for oil lubricated shafts), or Fresh Water Sample Test (for closed system fresh water lubricated shafts)		X	X	
Oil Sample Examination (for oil lubricated shafts), or Fresh Water Sample Test (for closed system fresh water lubricated).		X	X	

11.7 Other systems

11.7.1 Directional propeller and podded propulsion units for main propulsion purposes, inclusive of the propellers, shafts, gearing, control gear and the primary electrical components including any control and protection devices, are to be surveyed at intervals not exceeding five years. They are to be dismantled if considered necessary and generally examined as far as practicable. Non-destructive examination is to be carried out as considered necessary by the Surveyor on blade/fin roots. Consideration may be given to condition monitoring schemes for determining the condition of the unit.

11.7.2 Dynamic positioning and/or thruster-assisted mooring and athwartship thrust propellers and shaftings are to be surveyed at intervals not exceeding five years. They are to be generally examined so far as possible in dry dock and tested under working conditions afloat for satisfactory operation. All accessible parts, including sealing, locking and bearing faces, and any other moving parts are to be examined. Non-destructive examination is to be carried out as considered necessary by the Surveyor on blade/fin roots. Consideration may be given to condition monitoring schemes for determining the condition of the unit.

11.7.3 Water jet units for main propulsion purposes, including the impeller, casing, shaft, shaft seal, shaft bearing, inlet and outlet channels, steering nozzle, reversing arrangements, and control gear are to be surveyed at intervals not exceeding five years, provided the impeller shafts are made of approved corrosion-resistant material or have approved equivalent arrangements. They are to be generally examined so far as practicable.

11.7.4 Stationary supporting structure and any erosion protection inserts or doublers are to be examined in way of any propulsion devices.

11.8 Alternative arrangements

11.8.1 The Classification Committee will be prepared to give consideration to the circumstances of any special case upon application by the Owner, where the level of safety achieved is equivalent to that obtained by the survey methods described in this Section.

■ *Section 12*
Screwshafts, tube shafts, propellers and water jet units

12.1 Applicability

12.1.1 The requirements of this Section are only applicable to the first screwshaft survey on or after 1 January 2016 for craft delivered before 1 January 2016. For subsequent screwshaft surveys, *see Pt 1, Ch 3, 11 Screwshafts, tube shafts, propellers and water jet units*.

12.1.2 For screwshaft survey requirements on craft delivered on or after 1 January 2016, *see Pt 1, Ch 3, 11 Screwshafts, tube shafts, propellers and water jet units*.

12.2 Frequency of surveys

12.2.1 Shafts with keyed propeller attachments and fitted with continuous liners or approved oil glands, or made of approved corrosion resistant materials, are to be surveyed at intervals of five years when the keyway complies fully with the present Rules.

12.2.2 Shafts having keyless type propeller attachments are to be surveyed at intervals of five years provided they are fitted with approved oil glands or are made of approved corrosion resistant materials.

12.2.3 Shafts having solid coupling flanges at the after end are to be surveyed at intervals of five years provided they are fitted with approved oil glands or are made of approved corrosion resistant materials.

12.2.4 All other shafts not covered by *Pt 1, Ch 3, 12.2 Frequency of surveys 12.2.1* are to be surveyed at intervals of 2½ years.

12.2.5 Controllable pitch propellers for main propulsion purposes are to be surveyed at the same intervals as the screwshaft.

12.2.6 Directional propeller units for main propulsion purposes are to be surveyed at intervals not exceeding five years.

12.2.7 Water jet units for main propulsion purposes are to be surveyed at intervals not exceeding five years provided the impeller shafts are made of approved corrosion resistant material or have approved equivalent arrangements.

12.2.8 Athwartship thrust propellers and shaftings are to be surveyed at intervals not exceeding five years, *see Pt 1, Ch 3, 7.2 Complete Surveys 7.2.2*.

12.3 Normal surveys

12.3.1 All screwshafts are to be withdrawn for examination by LR's Surveyors at the intervals prescribed in *Pt 1, Ch 3, 12.2 Frequency of surveys 12.2.1*. The after end of the cylindrical part of the shaft and forward one third of the shaft cone, or fillet of the flange, is to be examined by a magnetic particle crack detection method. In the case of a keyed propeller attachment at least the forward one third of the shaft cone is to be examined with the key removed. Weardown is to be measured and the sterntube bearings, oil glands, propellers and fastenings are to be examined. Controllable pitch propellers where fitted are to be opened up and the working parts examined, together with the controlgear.

12.3.2 Directional propeller units are to be generally examined so far as possible, including the propellers, shafts, gearing, controlgear and primary electrical components, inclusive of control and protection devices.

12.3.3 Water jet units are to be generally examined so far as possible, including the impeller, casing, shaft, shaft seal, shaft bearing, inlet and outlet channels, steering nozzle, reversing arrangements, and controlgear. On completion an operational test is to be be carried out.

12.3.4 Stationary supporting structure and any erosion protection inserts or doublers are to be examined in way of any propulsion devices.

12.4 Screwshaft Condition Monitoring (SCM)

12.4.1 Monitoring records are to be reviewed at annual survey for all vessels assigned the ShipRight descriptive note SCM (Screwshaft Condition Monitoring). The records that are to be maintained for oil and water lubricated bearings are detailed in the following Sections.

12.4.2 Oil lubricated bearings records are to be available on board that include the following:

(a) Lubricating oil analysis to be carried out regularly at intervals not exceeding six months. Each analysis is to include the following minimum parameters:

- water content,
- chloride content,
- bearing material and metal particles content,
- oil ageing (resistance to oxidation) , minimum testing to include Viscosity and Total Acid Number (TAN).

Note Oil samples are to be taken under service conditions and are to be representative of the oil within the sterntube.

(b) Oil consumption.

(c) Bearing temperatures.

12.4.3 Further information is provided in the LR document *ShipRight Procedure Machinery Planned Maintenance and Condition Monitoring*.

12.4.4 Water lubricated bearings records are to be available on board that include the following:

(a) A record of variations in the flow rate of lubricating water.

(b) A record of variations in the shaft power transmission.

(c) Wear monitoring records for the sternbush.

(d) For open loop systems the records from equipment for continuous monitoring of water sediment or turbidity alternatively records from an LR approved extractive sampling and testing procedure are to be available on board.

Records of cleaning and replacement of lubrication filters/separators are to be maintained on board. The pumping and water filtration system is to be considered part of the continuous survey cycle and is to be subject to a Periodical Survey.

(e) For closed cycle water systems the records from water analysis results carried out regularly at intervals not exceeding six months are to be retained on board. The analysis is to include the following parameters:

(i) Chloride content.

(ii) Bearing material and metal particles content.

Note Samples are to be taken under service conditions and are to be representative of the water circulating within the sterntube.

Note Records of cleaning and replacement of lubrication filters/separators are to be maintained on board. The pumping and water filtration system is to be considered part of the continuous survey cycle and is to be subject to a Periodical Survey.

12.4.5 For maintenance of the descriptive note **SCM**, the records of all data collected in *Pt 1, Ch 3, 12.4 Screwshaft Condition Monitoring (SCM) 12.4.2* and *Pt 1, Ch 3, 12.4 Screwshaft Condition Monitoring (SCM) 12.4.4* are to be retained on board and audited by LR annually.

12.4.6 Where the requirements for the descriptive note **SCM** have been complied with, the screwshaft need not be withdrawn at surveys as required by *Pt 1, Ch 3, 12.3 Normal surveys 12.3.1*, provided all condition monitoring data are found to be within permissible limits and all exposed areas of the shaft are examined by a magnetic particle crack detection method or an alternative approved means for shafts with a protective liner or coating (*Pt 11, Ch 2, 5.2 Screwshaft Condition Monitoring (SCM) 5.2.3.(f)*). The remaining requirements of *Pt 1, Ch 3, 12.3 Normal surveys 12.3.1* are to be complied with. Where the attending Surveyor considers that the data presented is not sufficient to determine the condition of the shaft, the shaft may be required to be withdrawn in accordance with *Pt 1, Ch 3, 12.3 Normal surveys 12.3.1*. For water lubricated bearings, the screwshaft is to be withdrawn for examination, as *Pt 1, Ch 3, 12.3 Normal surveys 12.3.1*, when the ship reaches 18 years from the date of build or the third Special Survey, whichever comes first.

12.5 Modified Survey

12.5.1 A Modified Survey may be accepted at alternate five-yearly surveys for shafts described in *Pt 1, Ch 3, 12.2 Frequency of surveys 12.2.1* provided they are fitted with oil lubricated bearings and approved oil glands, and also for those in *Pt 1, Ch 3, 12.2 Frequency of surveys 12.2.2* and *Pt 1, Ch 3, 12.2 Frequency of surveys 12.2.3*.

12.5.2 The Modified Survey is to consist of the partial withdrawal of the shaft, sufficient to ascertain the condition of the stern bearing and shaft in way. For keyless propellers or shafts with a solid flange connection to the propeller a visual examination to confirm the good condition of the sealing arrangements is to be made. The oil glands are to be capable of being replaced without removal of the propeller. The forward bearing and all accessible parts including the propeller connection to the shaft are to be examined as far as possible. Wear down is to be measured and found satisfactory. Where a controllable pitch propeller is fitted, at least one of the blades is to be dismantled complete for examination of the working parts and the controlgear.

12.5.3 For keyed propellers, the after end of the cylindrical part of the shaft and forward one third of the shaft cone are to be examined by a magnetic particle crack detection method, for which dismantling of the propeller and removal of the key will be required.

12.5.4 Where the descriptive note **SCM** has been assigned as described in *Pt 1, Ch 3, 12.4 Screwshaft Condition Monitoring (SCM) 12.4.1* and all data is found to be within permissible limits, partial withdrawal of the shaft may not be required. Where doubt exists regarding any of the above findings the shaft is to be withdrawn to permit an entire examination.

12.6 Partial Survey

12.6.1 For shafts where the Modified Survey is applicable, upon application by the Owner, the Committee will be prepared to give consideration to postponement of the survey for a maximum period of half the specified cycle provided a Partial Survey is held.

12.6.2 The Partial Survey is to consist of the propeller being backed off in any keyed shaft and the top half of the cone examined by an efficient crack detection method for which removal of the key will be required. Oil glands and seals are to be examined and dealt with as necessary. Weardown is to be measured and found satisfactory. Propeller and fastenings are to be examined.

12.6.3 The Committee will be prepared to give consideration to the circumstances of any special case upon application by the Owner.

■ *Section 13*
Classification of craft not built under survey

13.1 General

13.1.1 When classification is desired for a craft not built under the supervision of LR's Surveyors, application should be made to the Committee in writing.

13.1.2 Periodical Surveys of such craft, when classed, are subsequently to be held as in the case of craft built under survey.

13.1.3 Where classification is desired for a craft which is classed by another recognised Society, special consideration will be given to the scope of the survey.

13.2 Hull and equipment

13.2.1 Plans showing the main scantlings and arrangements of the actual craft together with any proposed alterations are to be submitted for approval. These should comprise plans of the midship section, longitudinal section and decks, and such other plans as may be requested. If plans cannot be obtained or prepared by the Owner, facilities are to be given for LR's Surveyor to obtain the necessary information from the craft.

13.2.2 Particulars of the process of manufacture and the testing of the material of construction are to be supplied. The requirements for composite craft will be specially considered.

13.2.3 The full requirements of Sections *Pt 1, Ch 3, 5 Special Survey - General - Hull requirements* and *Pt 1, Ch 3, 6 Special Survey - Thickness measurement requirements for steel craft* are to be carried out as applicable. Craft of recent construction will receive special consideration.

13.2.4 During the survey, the Surveyors are to satisfy themselves regarding the workmanship and verify the approved scantlings and arrangements. For this purpose, and also in order to ascertain the amount of any deterioration of steel craft, parts of the structure will require to be gauged as necessary. Full particulars of the anchors, chain cables and equipment are to be submitted. For craft to which *Pt 15, Ch 1 Piping Design Requirements* applies, fire protection, detection and extinction are to be in accordance with the Rules.

13.2.5 When the full survey requirements indicated in *Pt 1, Ch 3, 13.2 Hull and equipment 13.2.3* and *Pt 1, Ch 3, 13.2 Hull and equipment 13.2.4* cannot be completed at one time, the Committee may consider granting an interim record for a limited period. The conditions regarding the completion of the survey will depend on the merits of each particular case, which should be submitted for consideration.

13.3 Machinery

13.3.1 To facilitate the survey, the following plans and particulars (plans of piping are to be diagrammatic), together with the particulars of the materials used in the construction of any boilers, air receivers and important forgings are to be submitted:

- Name of manufacturer of engine and gearbox including the manufacturer's type designation of engine and gearbox, together with the continuous shaft power of the engine at the crankshaft coupling with the revolutions per minute of crankshaft and propeller.
- General pumping arrangements, including air and sounding pipes (Builder's plan).
- Bilge, ballast and fuel oil pumping arrangements, including the capacities of the pumps on bilge service.
- Arrangement and dimensions of any steam pipes.
- Arrangement of fuel oil pipes and fittings at settling and service tanks.
- Arrangement of fuel oil piping in connection with oil burning installations.
- Fuel oil overflow systems, where these are fitted.
- Arrangement of boiler feed systems.
- Fuel oil settling, service and other fuel oil tanks not forming part of the craft's structure.
- Boilers and economisers.
- Air receivers.
- Crank, thrust, intermediate and screw shafting.
- Details of water jet or directional propeller units, if fitted.
- Clutch and reversing gear with methods of control.
- Reduction gearing.
- Propeller (including spare propeller if supplied) where the diameter exceeds 1 m.
- Electrical circuits.
- Arrangement of compressed air systems for main and auxiliary services.
- Arrangement of lubricating oil, other flammable liquids and cooling water systems for main and auxiliary services.
- Steering gear including control arrangement.
- Arrangement of exhaust system indicating materials, method of cooling, and if water spray injected, the method of draining.

13.3.2 Plans additional to those detailed in *Pt 1, Ch 3, 13.3 Machinery 13.3.1* are not to be submitted unless the machinery is of a novel or special character affecting classification.

13.3.3 Where remote and/or automatic controls are fitted to propulsion machinery and essential auxiliaries, a description of the scheme is to be submitted.

13.3.4 For new craft and craft which have been in service less than two years, calculations of the torsional vibration characteristics of the propelling machinery are to be submitted for consideration, as required for craft constructed under Special Survey. For older craft the circumstances will be specially considered in relation to their service record and type of machinery installed. Where calculations are not submitted, the Committee may require that the machinery certificate be endorsed to this effect. When desired by the Owner, the calculations and investigation of the torsional vibration characteristics of the machinery may be carried out by LR upon special request.

13.3.5 The main and auxiliary machinery, feed pipes, compressed air pipes and boilers are to be examined as required at Complete Surveys. Working pressures are to be determined from the actual scantlings in accordance with the Rules.

13.3.6 The screwshaft is to be drawn and examined.

13.3.7 Any steam pipes or oil burning installations are to be examined and tested as required by Pt 1, *Pt 1, Ch 3, 15 Boilers* or *Pt 1, Ch 3, 16 Steam pipes* of the *Rules and Regulations for the Classification of Ships*.

13.3.8 The bilge, ballast and fuel oil pumping arrangements are to be examined and amended, as necessary, to comply with the Rules.

13.3.9 The electrical equipment is to be examined as required at Complete Surveys.

13.3.10 The whole of the machinery, including essential controls, is to be tried under working conditions to the Surveyor's satisfaction.

■ *Section 14*
Classification of rigs not built under survey

14.1 General

14.1.1 When classification is desired for a rig not built under the supervision of LR's Surveyors, application should be made to the Committee in writing.

14.1.2 When the **RIGGING*** notation is assigned, Periodical Surveys are to be carried out.

14.1.3 Where classification is desired for a rig which is classed by another recognised Society, special consideration may be given to the scope of the survey.

■ *Section 1* General

1.1 Frequency of surveys

1.1.1 The requirements of this Chapter are applicable to the Periodical Surveys set out in *Pt 1, Ch 2, 4.5 Existing service craft and yachts - Periodical Surveys*. Except as amended at the discretion of the Committee, the periods between such surveys are as follows:

(a) Annual Surveys if required, *see Pt 1, Ch 2, 4.5 Existing service craft and yachts - Periodical Surveys 4.5.2*.
(b) Intermediate Surveys as required by *Pt 1, Ch 2, 4.5 Existing service craft and yachts - Periodical Surveys 4.5.5*.
(c) Bottom Surveys as required by, *Pt 1, Ch 2, 4.5 Existing service craft and yachts - Periodical Surveys 4.5.6* and *Pt 1, Ch 2, 4.5 Existing service craft and yachts - Periodical Surveys 4.5.7*.
(d) Special Surveys at five-yearly intervals, *see Pt 1, Ch 2, 4.5 Existing service craft and yachts - Periodical Surveys 4.5.11*. For alternative arrangements, *see also* Ch 2,*Pt 1, Ch 2, 4.5 Existing service craft and yachts - Periodical Surveys 4.5.12*, *Pt 1, Ch 2, 4.5 Existing service craft and yachts - Periodical Surveys 4.5.13* and *Pt 1, Ch 2, 4.5 Existing service craft and yachts - Periodical Surveys 4.5.18*.
(e) Complete Surveys of machinery at five-yearly intervals, *see Pt 1, Ch 2, 4.5 Existing service craft and yachts - Periodical Surveys 4.5.20*. For alternative arrangements, *see also Pt 1, Ch 2, 4.5 Existing service craft and yachts - Periodical Surveys 4.5.21*, *Pt 1, Ch 2, 4.5 Existing service craft and yachts - Periodical Surveys 4.5.22*, *Pt 1, Ch 2, 4.5 Existing service craft and yachts - Periodical Surveys 4.5.25*, *Pt 1, Ch 2, 4.5 Existing service craft and yachts - Periodical Surveys 4.5.26* and *Pt 1, Ch 2, 4.5 Existing service craft and yachts - Periodical Surveys 4.5.26*.

1.1.2 For yachts assigned the **Laid-up** notation, in order to maintain the yacht in class a general examination of the hull and machinery is to be carried out in lieu of the normal Intermediate Survey requirements and in addition an Underwater Examination (UWE) is to be carried out in lieu of the normal Special Survey requirements, *see Pt 1, Ch 4, 2.1 General 2.1.2*, *Pt 1, Ch 4, 4.1 General 4.1.5* and *Pt 1, Ch 4, 6.1 Intermediate and Bottom Surveys 6.1.3*.

1.1.3 When it has been agreed that the Complete Survey of the hull and machinery may be carried out on the Continuous Survey basis, all compartments of the hull and all items of machinery are to be opened for survey in rotation to ensure that the interval between consecutive examinations of each part will not exceed five years, *see Pt 1, Ch 2, 4.5 Existing service craft and yachts - Periodical Surveys 4.5.19* and *Pt 1, Ch 2, 4.5 Existing service craft and yachts - Periodical Surveys 4.5.22*.

1.1.4 For the frequency of surveys of screwshafts, tube shafts, propellers and water jet units, *see Pt 1, Ch 4, 11 Screwshafts, tube shafts, propellers and water jet units*.

1.2 Surveys for damage or alterations

1.2.1 At any time when a yacht is undergoing alterations or damage repairs, any exposed parts of the structure normally difficult to access are to be specially examined, e.g. if any part of the main or auxiliary machinery is removed for any reason, the hull structure in way is to be carefully examined by the Surveyor, or when cement in the bottom or sheathing on decks is removed the structure in way is to be examined before the cement or sheathing is relaid.

1.3 Unscheduled surveys

1.3.1 In the event that Lloyd's Register (hereinafter referred to as 'LR') has cause to believe that its Rules and Regulations are not being complied with, LR reserves the right to perform unscheduled surveys of the hull and machinery as well as the applicable statutory requirements whether or not the appropriate statutory certificate has been issued by LR.

1.3.2 In the event of significant damage or defect affecting any yacht, LR reserves the right to perform unscheduled surveys of the hull or machinery of other similar yachts classed by LR and deemed to be vulnerable.

1.4 Surveys for the issue of Convention certificates

1.4.1 Surveys are to be held by LR when so appointed, or by the Exclusive Surveyors to a National Administration or by an IACS Member when so authorised by the National Authority, or, in the case of Cargo Ship Safety Radio Certificates or Safety Management Certificates, by any organisation authorised by the National Authority. In the case of dual classed craft, Convention Certificates may be issued by the other Society with which the craft is classed provided this is recognised in a formal Dual Class Agreement with LR and provided the other Society is also authorised by the National Authority.

1.5 Definitions

1.5.1 A **Ballast tank** is a tank which is used primarily for salt water ballast.

1.5.2 **Spaces** are separate hull compartments including integral tanks.

1.5.3 **Suspect areas** are locations within the hull structure vulnerable to increased likelihood of structural deterioration and may include:

(a) For steel hulls, areas of substantial corrosion and/or fatigue cracking.
(b) For aluminium alloy hulls, areas of fatigue cracking and areas in the vicinity of bimetallic connections.
(c) For composite hulls, areas subject to impact damage.
(d) For wood hulls, areas subject to decay as a result of fresh water ingress or poor ventilation.
(e) For high speed craft (as defined in *Pt 1, Ch 2, 2.2 Definitions 2.2.7*), areas of the bottom structure forward prone to slamming damage.
(f) For sailing craft, areas subject to high local stresses due to rigging loads and ballast keel attachments.

1.5.4 **Substantial corrosion** is wastage of individual steel or aluminium plates and stiffeners in excess of 75 per cent of allowable margins, but within acceptable limits.

1.5.5 **Protective coatings** for steel craft should usually be hard coatings. Other coating systems (e.g. soft coating) may be considered acceptable as alternatives provided they are applied and maintained in compliance with the manufacturer's specification.

1.5.6 **Coating condition** for steel yacht is defined as follows:

GOOD	Condition with only minor spot rusting.
FAIR	Condition with local breakdown of coating at edges of stiffeners and weld connections and/or light rusting over 20 per cent or more of areas under consideration, but less than as defined for POOR condition.
POOR	Condition with general breakdown of coating over 20 per cent or more of areas or hard scale at 10 per cent or more of areas under consideration.

1.5.7 A **Prompt and Thorough Repair** is a permanent repair completed at the time of survey to the satisfaction of the Surveyor, therein removing the need for the imposition of any associated condition of class or recommendation.

1.5.8 **Air pipe heads** installed on the exposed decks are those extending above the freeboard deck or superstructure decks.

1.6 Repairs

1.6.1 Any damage in association with wastage over the allowable limit (including buckling, grooving, detachment or fracture), or extensive areas of wastage over the allowable limits, which affects or, in the opinion of the Surveyor, will affect the yacht's structural, watertight or weathertight integrity, is to be promptly and thoroughly repaired. Areas to be considered include, (where fitted):

- side shell frames, their end attachments and adjacent shell plating;
- deck structure and deck plating;
- bottom structure and bottom plating;
- side structure and side plating;
- inner bottom structure and inner bottom plating;
- inner side structure and inner side plating;
- watertight or oiltight bulkheads;
- hatch covers and hatch coamings;
- the weld connection between air pipes and deck plating;
- air pipe heads installed on the exposed decks;
- ventilators, including closing devices.

For locations where adequate repair facilities are not available, consideration may be given to allow the yachts to proceed directly to a repair facility. This may require discharging the cargo and/or temporary repairs for the intended voyage.

1.6.2 Additionally, when a survey results in the identification of structural defects or corrosion, either of which, in the opinion of the Surveyor, will impair the yacht's fitness for continued service, remedial measures are to be implemented before the yacht continues in service.

1.6.3 Where the damage found on structure mentioned in *Pt 1, Ch 4, 1.6 Repairs 1.6.1* is isolated and of a localised nature which does not affect the yacht's structural integrity (as, for example, a localised, isolated and very minor hole in a deck), consideration may be given by the Surveyor to allow an appropriate temporary repair to restore watertight or weathertight integrity after careful evaluation of the surrounding structure and impose an associated Condition of Class with a specific short-term time limit in order to complete the repair and retain classification.

■ *Section 2*
Intermediate Surveys - Hull and machinery requirements

2.1 General

2.1.1 At Intermediate Surveys, the Surveyor is to examine the hull and machinery, so far as necessary and practicable, in order to be satisfied as to their general condition.

2.1.2 For yachts assigned the **Laid-up** notation, in lieu of the normal Intermediate Survey requirements a general examination of the hull and machinery is to be carried out.

2.2 Intermediate Surveys

2.2.1 The Surveyor is to be satisfied regarding:

(a) The efficient condition of hatchways on freeboard and superstructure decks, weather deck plating, ventilator coamings and air pipes, exposed casings, skylights, flush deck scuttles, deckhouses and companionways, superstructure bulkheads, side, bow and stern doors, windows and storm shutters, side scuttles and deadlights, chutes and other openings, together with all closing appliances and flame screens.

(b) The efficient condition of scuppers and sanitary discharges (so far as is practicable); valves on discharge lines (so far as is practicable) and their controls; guard rails and bulwarks; freeing ports, gangways and life-lines.

(c) The efficient condition of bilge level detection and alarm systems on yachts assigned a **UMS** notation.

2.2.2 The anchoring and mooring equipment including anchor warps or wire ropes is to be examined so far as is practicable. For all yachts over 10 years of age the anchors are to be partially lowered and raised using the windlass.

2.2.3 The watertight doors in watertight bulkheads are to be examined and operationally tested locally and where applicable remotely. Other watertight bulkhead penetrations are to be examined so far as is practicable.

2.2.4 The Surveyor is to examine and test in operation all main and auxiliary steering arrangements including their associated equipment and control systems.

2.2.5 The Surveyor is to generally inspect the machinery spaces with particular attention being given to the propulsion system, auxiliary machinery and to the existence of any fire and explosion hazards. Where applicable, emergency escape routes are to be checked to ensure that they are free of obstruction.

2.2.6 The means of communication between the navigating bridge and the machinery control positions, as well as the bridge and the alternative steering position, if fitted, are to be tested.

2.2.7 The bilge pumping systems and bilge wells, including operation of extended spindles, self closing drain cocks and level alarms, where fitted, are to be examined so far as is practicable. Satisfactory operation of the bilge pumps, including any hand pumps, is to be proven.

2.2.8 Any pressure vessels including safety devices, foundations, controls, relieving gear, associated piping systems, insulation and gauges, are to be generally examined. Surveyors should confirm that Periodical Surveys of pressure vessels have been carried out as required by the Rules and that the safety devices have been tested.

2.2.9 The electrical equipment and cabling forming the main and emergency electrical installations are to be generally examined under operating conditions so far as is practicable. The satisfactory operation of the main and emergency sources of power and electrical services essential for safety in an emergency is to be verified; where the sources of power are automatically controlled they should be tested in the automatic mode. Bonding straps for the control of static electricity and earthing arrangements are to be examined where fitted.

2.2.10 The electrical generating sets are to be examined under working conditions.

2.2.11 For yachts having **UMS** or **CCS** notation, a General Examination of automation equipment is to be carried out. Satisfactory operation of safety devices and control systems is to be verified.

2.2.12 For yachts to which *Pt 17, Ch 1 Fire Protection, Detection and Extinction – General* applies, the arrangements for fire protection, detection and extinction are to be examined and are to include the following items, as required to be fitted in accordance with the Rules:

(a) Verification, so far as is practicable, that no significant changes have been made to the arrangement of structural fire protection.
(b) Verification of the operation of manual and/or automatic doors where fitted.
(c) Verification that fire control plans are properly posted.
(d) Examination, so far as is possible, and testing as feasible, of the fire and/or smoke detection and alarm system(s).
(e) Examination of fire main system, and confirmation that each fire pump, including the emergency fire pump can be operated separately so that the required jets of water can be produced simultaneously from different hydrants.
(f) Verification that fire-hoses, nozzles, applicators and spanners are in good working condition and situated at their respective locations.
(g) Examination of fixed fire-fighting systems controls, piping, instructions and marking, checking for evidence of proper maintenance and servicing, including date of last systems tests.
(h) Verification that all portable and semi-portable fire-extinguishers are in their stowed positions, checking for evidence of proper maintenance and servicing, conducting random checks for evidence of discharged containers.
(i) Verification, so far as is practicable, that the remote control for stopping fans and machinery and shutting off fuel supplies in machinery spaces and, where fitted, the remote controls for stopping fans in accommodation spaces and the means of cutting off power to the galley are in good working order.
(j) Examination of the closing arrangements of ventilators, skylights and doorways where applicable.
(k) Verification that the fireman's outfits are complete and in good condition.
(l) Verification that gas installations for domestic purposes comply with the relevant statutory requirements.

2.2.13 For steel yachts a general examination of salt water ballast tanks, integral sanitary tanks and bilges is to be carried out as required below. If such inspections reveal no visible structural defects then the examination may be limited to a verification that the protective coating remains in GOOD condition as defined in *Pt 1, Ch 4, 1.5 Definitions 1.5.6*. When considered necessary by

the Surveyor thickness measurement of the structure is to be carried out. Where the protective coating is found to be other than in GOOD condition, and it has not been repaired, maintenance of class will be subject to the spaces in question being internally examined and gauged as necessary annually.

(a) For all yachts over five years of age and up to 10 years of age, representative salt water ballast tanks, integral sanitary tanks and bilges are to be generally examined. Where the protective coating is found to be other than in GOOD condition, as defined in *Pt 1, Ch 4, 1.5 Definitions 1.5.6*, or other defects are found, the examination is to be extended to other spaces of the same type.
(b) For steel yachts over 10 years of age all salt water ballast tanks, integral sanitary tanks and bilges are to be generally examined.

2.2.14 Representative internal spaces including fore and aft peak spaces, machinery spaces, bilges, etc are to be generally examined. These spaces should include all suspect areas, *see Pt 1, Ch 4, 1.5 Definitions 1.5.3*.

2.2.15 Rigs used for propulsion using wind force, associated structure and equipment, where fitted, are to be examined and operated as far as practicable and confirmed to be satisfactory.

■ *Section 3*
Bottom Surveys and In-Water Surveys - Hull and machinery requirements

3.1 General

3.1.1 At Bottom Surveys the Surveyor is to examine the outside of the craft's bottom and associated appendages, including rudders, propellers and thrusters.

3.2 Bottom Surveys in Dry-Dock

3.2.1 Where a yacht is in dry-dock or on a slipway, it is to be placed on blocks of sufficient height and proper staging is to be erected as may be necessary, for the examination of the outside of the hull, rudder(s) and underwater fittings. The outside surface of the hull is to be cleaned as may be required by the Surveyor.

3.2.2 Attention is to be given to parts of the external hull structure particularly liable to structural deterioration from causes such as high stresses, chafing and lying on the ground, and to areas of structural discontinuity.

3.2.3 The following parts of the external hull structure are to be specially examined:

(a) For steel hulls attention is to be given to parts of the structure particularly liable to excessive corrosion and to any undue unfairness of the plating of the bottom. The coating system is to be examined and made good as necessary.
(b) For aluminium alloy hulls, attention is to be given to areas adjacent to any bimetallic connections at skin fittings, etc.
(c) For composite hulls, the gelcoat or other protective finish is to be examined for surface cracking, blistering or other damage which may impair the efficiency of the protection to the underlying laminate.
(d) For wood hulls, the condition of any caulking or sheathing is to be examined as applicable. The condition of external fastenings may require to be confirmed by removal at the discretion of the Surveyor.
(e) For sailing or auxiliary yachts fitted with external ballast, the attachment of bilge or centreline ballast keels is to be examined.

3.2.4 Where required by the Rules, the satisfactory condition of the cathodic protection is to be confirmed.

3.2.5 Visible parts of the rudder, rudder pintles, rudder stock and couplings and sternframe are to be examined. The pintles are to be examined either by removal of the inspection plates or if considered necessary by the Surveyor, the rudder is to be lifted to enable examination. The clearances in the rudder bearings and pintles are to be measured. Where considered necessary by the Surveyor rudders are to be lifted for examination of the stock. The securing of rudder couplings and/or pintle fastenings is to be confirmed.

3.2.6 The sea chests, sea connections, scuppers and sanitary discharges, their attachments to the hull and the gratings at the sea inlets are to be examined.

3.2.7 Visible parts of the propeller(s) and sternbush(es), are to be examined. The clearance in the sternbush and the efficiency of the oil gland, if fitted, are to be ascertained and recorded. For controllable pitch propellers, the Surveyor is to be satisfied with the fastenings and tightness of hub and blade sealing.

3.2.8 The clearance of any shaft bracket bearings is to be ascertained.

3.2.9 The inboard shaft seals or glands are to be examined. Where flexible stern glands are fitted, the satisfactory condition of the rubber hose and securing clips is to be confirmed.

3.2.10 Special attention is to be given to the hull in way of underwater fittings such as transverse thrusters, stabilisers, etc.

3.2.11 Where applicable, attention is to be given to the connection and/or intersection of the cross-deck structure to the hulls of multi hull craft.

3.2.12 Visible parts of side thrusters are to be examined. Other propulsion systems which also have manoeuvring characteristics (such as directional propellers, vertical axis propellers, water jet units) are to be examined externally with focus on the condition of gear housing, propeller blades, bolt locking and other fastening arrangements. Sealing arrangements of propeller blades, propeller shaft and steering column are to be verified.

3.2.13 Where water jet units are fitted, the impeller, hull ducting, grating, nozzle steering and reversing arrangements are to be examined as far as is practicable.

3.2.14 Where transom mounted propulsion units are fitted, the steering arrangements and any flexible transom seals are to be examined.

3.2.15 When chain cables are ranged, the anchors and cables are to be examined by the Surveyor, *see also Pt 1, Ch 4, 4.3 Examination and testing - General 4.3.7* and *Table 4.4.1 Survey preparation*.

3.2.16 To maintain an ***IWS** notation, at completion of each dry-docking the condition of the high resistance paint is to be confirmed, and as applicable, satisfactory access arrangements to take the sternbush clearance and rudder pintle/bearing clearances are to be verified.

3.2.17 Where the anti-fouling system is changed completely, or partial repair is carried out affecting 25 per cent or more of the system, the coating specification and anti-fouling system is to be examined by the Surveyor in accordance with the *AFS - International Convention on the Control of Harmful Anti-Fouling Systems on Ships, 2001* and *Ch 15 Corrosion Prevention* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2021*

3.3 In-Water Surveys

3.3.1 The Committee will accept an In-Water Survey at alternate Bottom Surveys on yachts where an ***IWS** notation is assigned, *see Pt 1, Ch 2, 3.8 Other hull notations 3.8.2*.

3.3.2 The Committee may accept an In-Water Survey at alternate Bottom Surveys on yachts where suitable protection is applied to the underwater portion of the hull. If requested, an ***IWS** class notation may be assigned on satisfactory completion of the Survey, provided that the applicable requirements of the Rules are complied with, *see* also *Pt 1, Ch 2, 3.8 Other hull notations 3.8.2*.

3.3.3 In-Water Survey is to provide the information normally obtained from the Bottom Survey in dry-dock, so far as is practicable. However, for oil lubricated sternbush arrangements, the clearance in the sternbush is not required to be ascertained subject to the Surveyor confirming satisfactory operating history and condition data records (lubricating oil analysis, bearing temperature, lubricating oil consumption) and verifying satisfactory operation of the screwshaft.

3.3.4 Proposals for In-Water Surveys are to be submitted in advance of the survey being required so that satisfactory arrangements can be agreed with LR.

3.3.5 The In-Water Survey is to be carried out at agreed geographical locations under the surveillance of a Surveyor to LR, with the yacht in sheltered waters; the in-water visibility is to be good and the hull below the waterline is to be clean. The Surveyor is to be satisfied with the methods of orientation of the divers on the plating, which should make use where necessary of permanent markings on the plating at selected points.

3.3.6 The In-Water Survey is to be carried out by a qualified diver employed by a firm approved by LR. In addition, for certain aspects of the In-Water Survey, consideration may be given to the use of a Remotely Operated Vehicle (ROV) operated by the LR approved firm.

3.3.7 The Surveyor is to be satisfied that the method of pictorial presentation is satisfactory. There is to be good two-way communication between the Surveyor and the diver.

3.3.8 If the In-Water Survey reveals damage or deterioration that requires early attention, the Surveyor may require that the yacht be dry-docked in order that a fuller survey can be undertaken and the necessary work carried out.

Section 4
Special Survey - General - Hull requirements

4.1 General

4.1.1 The survey is to be of sufficient extent to ensure that the hull and related equipment is in satisfactory condition and is fit for its intended purpose, subject to proper maintenance and operation and to Periodical Surveys being carried out as required by the Regulations.

4.1.2 The requirements of *Pt 1, Ch 4, 2 Intermediate Surveys - Hull and machinery requirements* are to be complied with so far as applicable.

4.1.3 A Bottom Survey in accordance with the requirements of *Pt 1, Ch 4, 3.2 Bottom Surveys in Dry-Dock* is to be carried out as part of the Special Survey.

4.1.4 For sailing and auxiliary yachts fitted with unclassed machinery installations the requirements of *Pt 1, Ch 4, 12.3 Complete Surveys 12.3.1* are to be complied with.

4.1.5 For yachts assigned the **Laid-up** notation, an Underwater Examination (UWE) and general examination of hull and machinery is to be carried out in lieu of the normal Special Survey requirements.

4.2 Preparation

4.2.1 The yacht is to be prepared for survey in accordance with the requirements of *Table 4.4.1 Survey preparation*. The preparation should be of sufficient extent to facilitate an examination to ascertain any excessive corrosion, erosion, deformation, fractures, damages and other structural deterioration.

Table 4.4.1 Survey preparation

Special Survey I (Yachts 5 years old)	Special Survey II (Yachts 10 years old)	Special Survey III (Yachts 15 years old) and subsequent special surveys
(1) The interior of the yacht is to be sufficiently opened out by the removal of lining, ceiling/ cabin sole, portable tanks and ballast, etc as required in order that the Surveyor may be satisfied as to the condition of suspect areas of the structure, *see Pt 1, Ch 4, 1.5 Definitions 1.5.3*. A record is to be made of those areas where lining, cabin sole etc. were opened out and where equipment was removed during the survey. This record is to be retained for reference during subsequent surveys.	In addition to the requirements for Special Survey I, the following are to be complied with: (1) The chain locker is to be cleared and cleaned internally for examination of the structure and examination of the cable securing arrangements. The chain cables/ anchor warps, as applicable, are to be ranged for inspection. The anchors are to be cleaned and placed in an accessible position for inspection.	In addition to the requirements for Special Survey II the following are to be complied with: (1) Linings, ceiling/cabin soles, etc. are to be removed as required in order that the Surveyor may be satisfied as to the condition of the structure. For steel yachts: (2) Portions of wood sheathing, or other covering, on steel decks are to be removed, as considered necessary by the Surveyor, in order to ascertain the condition of the plating.
(2) Machinery compartments, fore and aft peaks and other spaces as directed by the Surveyor, are to be cleared and cleaned as necessary, and the bilges and limbers all fore and aft are to be cleaned and prepared for examination. Platform plates in engine spaces are to be lifted as may be necessary for the examination of the structure below. Where necessary, pipework may be required to be removed for examination of the structure.	(2) The rudder is to be unshipped for examination of the rudder stock and trunk at the discretion of the Surveyor. For sailing or auxiliary yachts: (3) On yachts fitted with an external ballast keel, fastenings are to be drawn for examination as may be required by the Surveyor.	(3) Where spaces are insulated, sufficient insulation is to be removed in each space to enable the Surveyors to be satisfied with the condition of the structure. (4) Linings are to be removed in way of shell plating immediately above tank top connections to the side shell, in way of galleys/washrooms and beneath portlights and windows. For sailing or auxiliary yachts:

(3) In way of the single and/or double bottom areas, a sufficient amount of cabin sole is to be lifted to permit examination of the bilges and/or tanktops below.	(4) On yachts fitted with a centreplate or lifting keel, the pivot bolts and lifting arrangements are to be dismantled for examination as required by the Surveyor. For wood yachts:	(5) On yachts fitted with an external ballast keel, a minimum of 50% of the total number of ballast keel fastenings are to be drawn for examination as required by the Surveyor. If defects are found the remaining fastenings should be drawn for examination.
(4) All integral tanks are to be cleaned as necessary to permit examination. (For steel yachts *see Table 4.4.2 Tank internal examination requirements for steel yachts*).	(5) Where the hull is sheathed with metal, such sheathing as will permit an examination of the stem, wood keel, garboards, plank ends and sternpost is to be removed as required by the Surveyor.	For wood yachts:
(5) The masts and the sail/wind propulsion system are to be unshipped for survey. The whole of the standing rigging, including rigging screws, bolts, pins and fittings, is to be fully or partly disassembled as considered necessary by the Surveyor. **Note** This requirement may be waived at alternate Special Surveys or when the construction does not allow disassembly, provided that the masts and rigging are thoroughly examined *in situ*.	(6) Fastenings are to be drawn as may be required by the Surveyor. (7) The outside surface of the planking is to be scraped bright at the discretion of the Surveyor.	(6) Where iron or mild steel fastenings are used, as a minimum requirement the following are to be drawn for examination where applicable: • 6 floor arm fastenings each side. • 4 hanging knee fastenings each side. • 4 chain plate fastenings each side at each mast. • 18 frame to plank fastenings each side. • 12 garboard and 12 plank end fastenings each side.
Note ‘unshipped’ means removed from its fixed or regular position and lay down, providing access for Close-up Survey. ‘disassembled’ means to dismantle and laying out all lines, tackles and other removable parts to the extent necessary to establish the condition of the rigging components.		

4.2.2 Where, in accordance with *Table 4.4.1 Survey preparation*, the yacht is opened out by removal of linings, cabin sole etc. and defects are found, further opening out will be required in order that the Surveyor can confirm the full extent of the defects.

4.3 Examination and testing - General

4.3.1 All spaces within the hull and superstructure including integral tanks are to be examined (*see also Pt 1, Ch 4, 4.4 Examination and testing - Additional items for steel yachts 4.4.1* for tank examinations on steel craft). Special attention is to be paid to any suspect areas, *see Pt 1, Ch 4, 1.5 Definitions 1.5.3*.

4.3.2 Double bottom compartments, peak tanks and all other integral tanks are to be tested by a head sufficient to give the maximum pressure that can be experienced in service. Tanks may be tested afloat provided that their internal examination is also carried out afloat.

4.3.3 Where repairs are effected to the hull shell or bulkheads, any integral tanks in way are to be tested to the Surveyor's satisfaction on completion of these repairs.

4.3.4 All decks, casings and superstructures are to be examined.

4.3.5 The satisfactory attachment of any wood or other deck sheathing is to be confirmed,*see also Pt 1, Ch 4, 4.4 Examination and testing - Additional items for steel yachts 4.4.4*.

4.3.6 Attention is to be given to the corners of openings and other discontinuities in the hull structure.

4.3.7 The anchors are to be examined. If the chain cables are ranged they are to be examined together with the chain locker, *see Table 4.4.1 Survey preparation*. If any length of chain cable is found to be reduced in mean diameter at its most worn part by 12 per cent or more from its nominal diameter, it is to be renewed. The windlass is to be examined.

4.3.8 The Surveyor is to be satisfied that there are suitable towlines and mooring ropes when these are a Rule requirement.

4.3.9 Rigs used for propulsion using wind force, associated structure and equipment, where fitted, are to be examined, *see Table 4.4.1 Survey preparation*. This examination may be undertaken by a Surveyor and/or by a firm approved by LR.

4.3.10 Representative structural fastenings are to be tested to ascertain their soundness and may require to be drawn for examination at the discretion of the Surveyor.

4.3.11 All watertight cable transits are to be examined to confirm their satisfactory condition by an LR Surveyor or by a firm approved as a service supplier in accordance with LR's *Procedures for Approval of Service Suppliers*. Where applicable, the electrical cables schedule of watertight penetrations (e.g. cable transit seal systems register) is to be reviewed to confirm it is being maintained, *see Pt 4, Ch 1, 4.5 Plans to be supplied to the unit* and *Pt 16, Ch 2, 11.11 Penetration of bulkheads and decks by cables*.

4.3.12 For yachts to which *Pt 17, Ch 1 Fire Protection, Detection and Extinction – General* applies, the Surveyor is to be satisfied as to the efficient condition of the means of escape from crew and passenger spaces, and spaces in which crew are normally employed.

4.3.13 Ship side valves (i.e. sea connections, scuppers and sanitary discharges) are to be tested once reassembled.

4.3.14 At Special Survey III and subsequent special surveys, structural downflooding ducts and structural ventilation ducts are to be internally examined.

4.4 Examination and testing - Additional items for steel yachts

4.4.1 All integral tanks are generally to be internally examined. However, in certain circumstances the internal examination of lubricating oil, fresh water and fuel oil tanks may be waived. For the minimum extent of tank internal examination *see Table 4.4.2 Tank internal examination requirements for steel yachts*.

Table 4.4.2 Tank internal examination requirements for steel yachts

Tank	Special Survey I (Yachts 5 years old)	Special Survey II (Yachts 10 years old)	Special Survey III (Yachts 15 years old)	Special Survey IV (Yachts 20 years old)	All Subsequent Special Surveys
Peaks	All tanks	All tanks	All tanks	All tanks	All tanks
Salt water ballast	All tanks	All tanks	All tanks	All tanks	All tanks
Lubricating oil	None	None	*See* Note 2	*See* Note 3	All tanks
Fresh water	None	*See* Note 1	*See* Note 2	*See* Note 3	All tanks
Fuel oil	None	*See* Note 1	*See* Note 2	*See* Note 3	All tanks
Sanitary	All tanks	All tanks	All tanks	All tanks	All tanks

Note 1. Tanks (excluding peak tanks) used exclusively for fuel oil or fresh water need not all be examined internally provided that the Surveyor is satisfied with the condition, after both external examination and testing and from an internal examination of the after end of one forward double bottom tank, and of one selected deep tank.

Note 2. Tanks (excluding peak tanks) used exclusively for fuel oil, fuel oil and fresh water ballast, or lubricating oil, need not all be examined internally provided that the Surveyor is satisfied with the condition, after both external examination and testing and from an internal examination of one double bottom tank forward and one aft and one deep tank.

Note 3. Tanks (excluding peak tanks) used exclusively for fuel oil, fuel oil and fresh water ballast, or lubricating oil, need not all be examined internally provided that the Surveyor is satisfied with the condition, after both external examination and testing and from internal examination of a least one double bottom tank amidships, one forward and one aft and one deep tank.

Note 4. When examining tanks internally the Surveyor is to verify that striking plates or other additional reinforcement is fitted under sounding pipes. In the case of tanks fitted only with remote gauging facilities, the satisfactory operation of the gauges is to be confirmed.

4.4.2 In salt water ballast spaces, integral sanitary tanks and bilges, where the protective coating is found to be other than in GOOD condition as defined in *Pt 1, Ch 4, 1.5 Definitions 1.5.6* and it has not been repaired, maintenance of class will be subject to the spaces in question being internally examined and gauged as necessary annually.

4.4.3 The protection of steelwork, other than as referred to in *Pt 1, Ch 4, 4.4 Examination and testing - Additional items for steel yachts 4.4.2* should be examined and made good where necessary on satisfactory completion of the survey. In areas where

the inner surface of the bottom plating is covered with cement, asphalt or other composition, the removal of this covering may be dispensed with, provided that it is found sound and adhering satisfactorily to the steel.

4.4.4 Wood decks or sheathing are to be examined and the caulking is to be tested and recaulked as necessary. If decay or rot is found, or the wood is excessively worn, the wood is to be renewed. When a wood deck, laid on stringers and ties, has worn by 20 per cent or more in thickness, it is to be renewed. Attention is to be given to the condition of the plating under wood deck sheathing or other deck covering. If it is found that such coverings are broken, or are not adhering closely to the plating, sections are to be removed as necessary to ascertain the condition of the plating, *see also Pt 1, Ch 4, 1.2 Surveys for damage or alterations 1.2.1*.

4.4.5 The structure in way of bimetallic connections e.g. to aluminium alloy deckhouses is to be examined.

4.4.6 The Surveyors may require to measure the thickness of the material in any portion of the structure where signs of wastage are evident or wastage is normally found. Any parts of the structure which are found defective or excessively reduced in scantlings are to be made good by materials of the approved scantlings and quality. The minimum requirements for thickness measurements are given in *Pt 1, Ch 4, 5 Special Survey - Thickness measurement requirements for steel yachts*.

4.5 Examination and testing - Additional items for aluminium alloy yachts

4.5.1 The structure in way of any bimetallic connections is to be examined and the efficiency of the insulation arrangements confirmed.

4.5.2 The Surveyor may require to measure the thickness of the material in any portion of the structure where signs of deterioration are evident or may normally be found. Any parts of the structure which are found defective or excessively reduced in scantlings are to be made good by materials of the approved scantlings and quality.

4.6 Examination and testing - Additional items for composite yachts

4.6.1 The bonded attachments of frames, floors, bulkheads, structural joinery, engine bearers, sterntubes, rudder tubes, and integral tank boundaries are to be examined.

4.6.2 The hull to deck joint together with any joints between the deck and deckhouses or superstructures are to be examined.

4.6.3 The structure in way of the bolted attachment of fittings including guardrail stanchions, windlass, shaft brackets, fendering, mooring bitts, mast steps, rigging chainplates, etc. is to be examined.

4.7 Examination and testing - Additional items for wood yachts

4.7.1 Where hulls are provided with metal sheathing, the condition of the structure in way of any sheathing is to be confirmed. For the extent of removal of metal sheathing *see Table 4.4.1 Survey preparation*. The satisfactory adhesion of any glass/nylon reinforced plastic sheathing is also to be confirmed.

4.7.2 Wood decks or sheathing are to be examined and the caulking is to be tested and re-caulked as necessary. If decay or rot is found or the wood has worn by 20 per cent or more in thickness, the wood is to be renewed. Attention is to be given to the condition of the structure under wood decks, and to fabric deck coverings. If it is found that such coverings are damaged or are not adhering closely to the deck, sections are to be removed as necessary to ascertain the condition of the deck under.

4.7.3 Fastenings as may be required by the Surveyor are to be drawn for examination, *see Table 4.4.1 Survey preparation*.

4.8 Examination and testing - Additional items for sailing and auxiliary yachts

4.8.1 The mast(s), mast steps, spars, standing and running rigging, rigging screws, chainplates and sails are to be examined, *see Table 4.4.1 Survey preparation*.

4.8.2 The structure in way of the attachment of bilge or centreline ballast keels is to be examined. Ballast keel bolts are to be tested to ascertain their soundness and may require to be drawn for examination, *see Table 4.4.1 Survey preparation*.

4.8.3 On yachts fitted with a centreplate or lifting keel, the pivot bolt and lifting arrangements are to be examined as far as is practicable.

■ *Section 5*
Special Survey - Thickness measurement requirements for steel yachts

5.1 General

5.1.1 Thickness measurements, as required by *Pt 1, Ch 4, 4 Special Survey - General - Hull requirements* are to be carried out in accordance with the following requirements.

5.1.2 Thickness measurements are to be taken at the forward and aft areas of all plates. In all cases the measurements are to represent the average of the multiple measurements taken on each plate. The extent of local substantial corrosion of plates is to be established by intensive measurement in the affected areas. Where measured plates are renewed, the thicknesses of adjacent plates in the same strake are to be reported.

5.1.3 Thickness measurements are normally to be by means of ultrasonic test equipment. For vessels less than 500 gross tons a suitably qualified exclusive Surveyor (where available) may carry out thickness measurements. On all other occasions, thickness measurements are to be carried out by a firm approved in accordance with LR's *Approval for Thickness Measurement of Hull Structures*.

5.1.4 Thickness measurements may be carried out in association with the fourth Annual Survey.

5.1.5 The minimum requirements for thickness measurement are indicated in *Table 4.5.1 Thickness measurement of steel yachts*.

5.1.6 The Surveyor may extend the scope of thickness measurement if deemed necessary.

5.1.7 The acceptance criteria for thickness measurements are according to the LR document *Thickness Measurement and Close-Up Survey Guidance.*

5.2 Thickness measurement reporting

5.2.1 A report is to be prepared by the approved firm carrying out the thickness measurement. The report is to give the location of measurement, the thickness measured as well as the corresponding original thickness. The report is to give the date when the measurement was carried out, the type of measuring equipment, names of personnel and their qualifications and is to be signed by the operator and supervisor.

5.2.2 The thickness measurement report is to be verified and signed by the Surveyor.

Table 4.5.1 Thickness measurement of steel yachts

Special Survey I (Yachts 5 years old)	Special Survey II (Yachts 10 years old)	Special Survey III (Yachts 15 years old)	Special Survey IV and subsequent (Yachts 20 years old and over)
Suspect areas, as required by the Surveyor and may include areas where the coatings are found to be other than in GOOD condition, *see* Note 1.	Suspect areas, as required by the Surveyor and may include areas where the coatings are found to be other than in GOOD condition, *see* Note 1.	(1) Any exposed plating throughout the Main Deck. (2) Shell plating in way of the waterline throughout the length of the craft.	(1) All Main Deck plating outside deckhouses or superstructures and including plating in way of wood deck planking or sheathing. (2) Shell plating in way of, and below, the waterline throughout the length of the craft.
		(3) Suspect areas, as required by the Surveyor may include areas where the coatings are found to be other than in GOOD condition, *see* Note 1.	(3) 2 transverse sections of deck and shell plating within 0.5*L* amidships. (4) Suspect areas, as required by the Surveyor and to include as applicable: (a) Areas where the coatings are found to be other than in GOOD condition (b) Shell and tanktop plating immediately adjacent to tank top margins. (c) Bottom shell in way of any cement, asphalt or other composition. (d) Shell plating below portlights and windows. (e) Tanktop plating below ceiling or cabin soles. (f) Deck plating and side shell plating in way of galleys, washrooms and refrigerated store spaces. (g) Structure in way of integral sanitary tanks.
Note 1. Suspect areas are locations within the hull structure vulnerable to increased likelihood of structural deterioration and may include, for steel hulls, areas of substantial corrosion and/or fatigue cracking, *see also Pt 1, Ch 4, 1.5 Definitions 1.5.3* and *Pt 1, Ch 4, 4.4 Examination and testing - Additional items for steel yachts 4.4.6*. Note 2. Coating condition for steel craft is defined in *Pt 1, Ch 4, 1.5 Definitions 1.5.6*.			

■ *Section 6*
Machinery surveys - General requirements

6.1 Intermediate and Bottom Surveys

6.1.1 For Intermediate and Bottom Surveys, *see* Sections *Pt 1, Ch 4, 2 Intermediate Surveys - Hull and machinery requirements* and *Pt 1, Ch 4, 3 Bottom Surveys and In-Water Surveys - Hull and machinery requirements*.

6.1.2 For yachts where an Approved Planned Maintenance Scheme is in operation an Annual Survey of the machinery is to be carried out together with an audit of the maintenance and monitoring records.

6.1.3 For yachts assigned the **Laid-up** notation, a general examination of the machinery is to be carried out in lieu of the normal Intermediate Survey requirements.

6.2 Complete Surveys

6.2.1 While the yacht is in dry-dock, all openings to the sea in the machinery spaces and pump-rooms, together with the valves, cocks and the fastenings with which these are connected to the hull, are to be examined. For athwartships thrust propellers, *see Pt 1, Ch 4, 11.2 Frequency of surveys 11.2.8*.

6.2.2 Athwartships thrust propellers are to be generally examined as far as is possible in dry dock and tested under working conditions afloat for satisfactory operation.

6.2.3 All shafts (except screwshafts and tube shafts, for which special arrangements are detailed in *Pt 1, Ch 4, 11 Screwshafts, tube shafts, propellers and water jet units*), thrust block and all bearings are to be examined. The lower halves of bearings need not be exposed if alignment and wear are found to be acceptable.

6.2.4 An examination is to be made as far as practicable of all propulsion gears complete with all wheels, pinions, shafts, bearings and gear teeth, thrust bearings and incorporated clutch arrangements.

6.2.5 The following auxiliaries and components are also to be examined:

(a) Auxiliary engines, auxiliary air compressors with their intercoolers, filters and/or oil separators and safety devices, and all pumps and components used for essential services.
(b) Steering machinery.
(c) Windlass and associated driving equipment, where fitted.
(d) The holding down bolts, chocks or resilient mounts of main and auxiliary engines, gearcases, thrust blocks and intermediate shaft bearings.

6.2.6 All air receivers for essential services, together with their mountings, valves and safety devices, are to be cleaned internally and examined internally and externally. If internal examination of the air receivers is not practicable, they are to be tested hydraulically to 1,3 times the working pressure.

6.2.7 The valves, cocks and strainers of the bilge system including bilge injection, are to be opened up as considered necessary by the Surveyor and together with pipes, are to be examined and tested under working conditions. The fuel oil, feed, lubricating oil and cooling water systems also any ballast connections together with all pressure filters, heaters and coolers used for essential services, are to be opened up and examined or tested, as considered necessary by the Surveyor. All safety devices for the foregoing items are to be examined.

6.2.8 Fuel tanks which do not form part of the yacht's structure are to be examined, and if considered necessary by the Surveyor, they are to be tested to the pressure specified for new tanks. The tanks need not be examined internally at the first survey if they are found satisfactory on external inspection. The mountings, fittings and remote controls of all fuel oil tanks are to be examined, so far as is practicable.

6.2.9 Where remote and/or automatic controls are fitted for essential machinery, they are to be tested to demonstrate that they are in good working order.

6.2.10 In addition to the above, detailed requirements for gas turbines and oil engines and electrical installations are given in Sections *Pt 1, Ch 4, 7 Gas turbines - Detailed requirements*, *Pt 1, Ch 4, 8 Oil engines - Detailed requirements* and *Pt 1, Ch 4, 9 Electrical equipment* respectively. In certain instances, upon application by the Owner or where indicated by the maker's servicing recommendations, the Committee will give consideration to the circumstances where deviation from these detailed requirements is warranted, taking account of design, appropriate indicating equipment (e.g. vibration indicators) and operational records, *see Pt 1, Ch 2, 4.5 Existing service craft and yachts - Periodical Surveys 4.5.21* and *Pt 1, Ch 2, 4.5 Existing service craft and yachts - Periodical Surveys 4.5.27*.

■ *Section 7*
Gas turbines - Detailed requirements

7.1 Complete Surveys

7.1.1 The requirements of *Pt 1, Ch 4, 6 Machinery surveys - General requirements* are to be complied with. *See Pt 1, Ch 4, 6.2 Complete Surveys 6.2.10* regarding any deviation from the following.

7.1.2 The following parts are to be opened out and examined:

- Compressor including impellers or blading, rotors and casing.
- Combustion chambers, burners, intercoolers and heat exchangers.
- Gas, air and fuel piping and fittings.
- Gas generator turbine and power turbine blading, rotors and casing
- Rotors to include couplings, clutches, bearings and tie bolts.
- Auxiliary mounted fuel, L.O. and cooling water pumps, their drive transmissions and fittings.
- Starting system (for starting air pipes, *see Pt 1, Ch 4, 8.1 Complete Surveys 8.1.3*).
- All safety devices and local controls.
- Mountings and support frame.

7.1.3 The compressor/turbine units are to be operated and maintained in accordance with the manufacturer's instructions. Overhauls, including the prescribed replacement of limited life components, are to be undertaken at the specified intervals. Full service records are to be available for review by the Surveyor.

7.1.4 The manoeuvring of the propulsion system is to be tested under working conditions.

■ *Section 8*
Oil engines - Detailed requirements

8.1 Complete Surveys

8.1.1 The requirements of *Pt 1, Ch 4, 6 Machinery surveys - General requirements* are to be complied with. *See Pt 1, Ch 4, 6.2 Complete Surveys 6.2.10* regarding any deviation from the following.

8.1.2 The following parts are to be opened out and examined:

- Cylinders and covers.
- Valves and valve gear.
- Pistons and connecting rods.
- Crankshafts and all bearings.
- Crankcases and entablatures.
- Crankcase door fastenings and explosion relief devices.
- Turbochargers and their associated coolers.
- Air compressors and their intercoolers.
- Filters and/or separators and safety devices.
- Fuel pumps and fittings.
- Camshaft drives and balancer units.
- Vibration dampers or detuners.
- Flexible couplings and clutches.
- Reverse gears.
- Attached pumps and cooling arrangements.

8.1.3 Selected pipes in the starting air system, if fitted, are to be removed for internal examination and are to be hammer tested. If any appreciable amount of lubricating oil is found in the pipes, the starting air system is to be thoroughly cleaned internally by steaming out, or other suitable means. Some of the pipes selected are to be those adjacent to the starting air valves at the cylinders and to the discharges from the air compressors.

8.1.4 The electric ignition system, if fitted, is to be examined and tested.

8.1.5 The manoeuvring of engines is to be tested under working conditions. Initial starting arrangements are to be tested.

Section 9
Electrical equipment

9.1 Intermediate Surveys

9.1.1 The requirements of *Pt 1, Ch 4, 2.2 Intermediate Surveys 2.2.9* and *Pt 1, Ch 4, 2.2 Intermediate Surveys 2.2.13* are to be complied with as far as applicable.

9.2 Complete Surveys

9.2.1 An electrical insulation resistance test is to be made on the electrical equipment and cables. The installation may be sub-divided or equipment, which may be damaged, disconnected for the purpose of this test.

9.2.2 The fittings on the main and emergency switchboards, section boards and distribution boards are to be examined and over-current protective devices and fuses inspected to verify that they provide suitable protection for their respective circuits.

9.2.3 Generator circuit-breakers are to be tested, so far as is practicable, to verify that protective devices including preference tripping relays, if fitted, operate satisfactorily.

9.2.4 The electric cables and their securing arrangements are to be examined, so far as is practicable, without undue disturbance of fixtures or casings unless opening up is considered necessary as a result of observation or of the tests required by *Pt 1, Ch 4, 9.2 Complete Surveys 9.2.1*.

9.2.5 The generator prime movers are to be surveyed as required by Sections *Pt 1, Ch 4, 7 Gas turbines - Detailed requirements* and *Pt 1, Ch 4, 8 Oil engines - Detailed requirements* and the governing of the engines tested. The motors concerned with essential services together with associated control and switch gear are to be examined and if considered necessary, are to be operated, so far as is practicable, under working conditions. All generators and steering gear motors are to be examined and are to be operated under working conditions, though not necessarily under full load or simultaneously.

9.2.6 Where transformers or electrical apparatus associated with supplies to essential services are liquid filled or cooled by a liquid in direct contact with current carrying parts, the owner is to arrange for samples of the liquid to be taken and tested, by a competent authority, in accordance with the equipment manufacturer's requirements, and a certificate giving the test results is to be furnished to the Surveyor.

9.2.7 Navigation light indicators are to be tried under working conditions, and correct operation on the failure of supply or failure of navigation lights verified.

9.2.8 The emergency sources of electrical power, where fitted, together with their automatic arrangements and associated circuits are to be tested.

9.2.9 Emergency lighting, transitional emergency lighting, supplementary emergency lighting, general emergency alarm and public address systems are to be tested as far as practicable.

9.2.10 Where the yacht is electrically propelled, the propulsion motors, generators, cables and all ancillary electrical gear, exciters and ventilating plant (including coolers) associated therewith are to be examined, and the insulation resistance to earth is to be tested. Special attention is to be given to windings, commutators and slip-rings. The operation of protective gear and alarm devices is to be checked, so far as is practicable. Liquids for filling and cooling, if used, are to be tested in accordance with *Pt 1, Ch 4, 9.2 Complete Surveys 9.2.6*. Interlocks intended to prevent unsafe operations or unauthorised access are to be checked to verify that they are functioning correctly. Emergency overspeed governors are to be tested.

9.2.11 Where batteries provide the source of power for any essential services, their installation, including charging and ventilation, is to be examined.

Section 10
Screwshafts, tube shafts, propellers and water jet units

10.1 Applicability

10.1.1 The requirements of this Section are applicable as follows:

(a) to craft delivered on or after 1 January 2016; and
(b) after the first screwshaft survey scheduled on or after 1 January 2016 for craft delivered before 1 January 2016.

10.1.2 For yachts delivered before 1 January 2016, the first screwshaft survey held on or after 1 January 2016 is to be held in accordance with the requirements of *Pt 1, Ch 4, 11 Screwshafts, tube shafts, propellers and water jet units*.

10.2 Definitions

10.2.1 **Adequate means for protection against corrosion**. An adequate means for protection against corrosion is an approved means for full protection of the shaft against sea water intrusion and subsequent corrosion attack. Such means are used for the protection of common steel material against corrosion particularly in combination with water lubricated bearings. Typical means are to be for example:

(a) continuous metallic, corrosion-resistant liners (*Pt 11, Ch 2, 4.14 Corrosion resistant liners on shafts*)
(b) continuous cladding,
(c) multiple layer synthetic coating,
(d) multiple layers of fiberglass,
(e) combinations of above mentioned,
(f) rubber/elastomer covering coating.

The means for protection against corrosion are to be installed/applied according to LR approved procedures.

10.2.2 **Fresh Water sample test**. At the Screwshaft Survey, a sample of the fresh water in a closed loop fresh water lubricated shaft is to be taken in the presence of a Surveyor. The requirements for Fresh Water sample tests are given in the *ShipRight Procedure Machinery Planned Maintenance and Condition Monitoring*.

10.2.3 **Lubricating oil analysis**. Lubricating oil analysis is to be carried out at regular intervals not exceeding six months. The documentation on lubricating oil analysis is to be available on board. Oil samples, to be submitted for the analysis, should be taken under service conditions.

10.2.4 **Oil sample examination**. An oil sample examination is a visual examination of the sterntube lubricating oil taken in the presence of a Surveyor, with a focus on water contamination.

10.2.5 **Service records**. Service records are regularly recorded data showing in-service conditions of the shaft(s) and are to include:

(a) For Oil Lubricated Stern Bearings: lubricating oil temperature, bearing temperature and oil consumption records.
(b) For Closed Loop System Fresh Water Lubricated Bearings: water flow, water temperature, salinity, pH, make-up water and water pressure (depending on design).

10.2.6 **Survey Methods on Closed Systems**. Oil Lubricated Shafts or Closed Loop System Fresh Water Lubricated Shafts:

(a) **TS Method 1** – Survey of screwshaft, tube shaft and propeller in accordance with the requirements of TS Method 1, *see* Table 4.10.3 Shaft survey methods. Primarily the shaft is withdrawn and the propeller is removed.
(b) **TS Method 2** – Survey of screwshaft, tube shaft and propeller in accordance with the requirements of TS Method 2, *see* Table 4.10.3 Shaft survey methods. Primarily records are reviewed, the propeller is removed but the shaft is not withdrawn.
(c) **TS Method 3** – Survey of screwshaft, tube shaft and propeller in accordance with the requirements of TS Method 3, *see* Table 4.10.3 Shaft survey methods. Primarily records are reviewed, the shaft is not withdrawn and the propeller is not removed.

10.2.7 **Survey Methods on Open Systems**. Water Lubricated Shafts:

(a) **TS Method 4** – Survey of screwshaft, tubeshaft and propeller in accordance with the requirements of TS Method 4, *see* Table 4.10.3 Shaft survey methods. Primarily the shaft is withdrawn and the propeller is removed.

10.2.8 **Tube shaft** is a shaft placed between the intermediate shaft and propeller shaft, normally arranged within a stern tube or running in open water. It may also be called a Stern Tube Shaft.

10.3 Closed Systems – Oil Lubricated Shafts or Closed Loop System Fresh Water Lubricated Shafts: Frequency of surveys

10.3.1 Oil lubricated shafts fitted with approved oil glands and closed loop system fresh water lubricated shafts fitted with approved adequate means of protection against corrosion or fabricated from corrosion resistant material are to be surveyed in accordance with *Pt 1, Ch 4, 10.3 Closed Systems – Oil Lubricated Shafts or Closed Loop System Fresh Water Lubricated Shafts:*

Frequency of surveys 10.3.2 to *Pt 1, Ch 4, 10.3 Closed Systems – Oil Lubricated Shafts or Closed Loop System Fresh Water Lubricated Shafts: Frequency of surveys 10.3.5*.

10.3.2 Shafts with a keyless propeller connection or a flanged propeller connection (including controllable pitch propellers for main propulsion purposes) are to be surveyed at intervals of five years in accordance with TS Method 1, 2 or 3.

10.3.3 Shafts with a keyed propeller connection with a keyway that complies fully with the present Rules are to be surveyed at intervals of five years in accordance with TS Method 1 or 2; TS Method 3 is not permitted.

10.3.4 For oil lubricated keyless shafts, the maximum interval between two surveys carried out according to TS Method 1 or TS Method 2 shall not exceed 15 years, except in the case when one extension for no more than three months is agreed.

10.3.5 Closed loop system fresh water lubricated shafts may be surveyed in accordance with TS Method 2 or for keyless shafts TS Method 3, only if the descriptive note **ShipRight SCM** is assigned. Notwithstanding this, the maximum interval between two surveys carried out according to TS Method 1 shall not exceed 15 years, except in the case when one extension for no more than three months is agreed.

10.3.6 Shaft configurations other than those listed in *Pt 1, Ch 4, 10.3 Closed Systems – Oil Lubricated Shafts or Closed Loop System Fresh Water Lubricated Shafts: Frequency of surveys 10.3.1* to *Pt 1, Ch 4, 10.3 Closed Systems – Oil Lubricated Shafts or Closed Loop System Fresh Water Lubricated Shafts: Frequency of surveys 10.3.5* above are to be surveyed at intervals of three years in accordance with TS Method 1.

10.3.7 TS Method 2 and TS Method 3 are only permitted where the prerequisite service records and data specified for those methods are to be provided. If at the time of survey the attending Surveyor is not satisfied with the service records and data presented, then the shaft may be required to be withdrawn. The service records and data are to be retained on board and audited by LR at the Annual Survey.

10.3.8 For oil lubricated arrangements, the descriptive note **ShipRight SCM** is not a prerequisite in order to hold TS Method 2 and TS Method 3.

10.3.9 In order to assign and maintain the descriptive note **ShipRight SCM,** the requirements of *Pt 11, Ch 2, 5.2 Screwshaft Condition Monitoring (SCM)* and *ShipRight Procedure Machinery Planned Maintenance and Condition Monitoring, Section 6* are to be complied with, including the requirements therein for onboard maintenance of records and review of them by the attending Surveyor at Annual Survey.

10.3.10 For surveys completed within three months before the shaft survey due date, the next period will start from the shaft survey due date.

10.3.11 *See* Summary of Survey Intervals and Extensions for closed systems in *Table 4.10.1 Summary of Survey Intervals and Extensions – Closed systems*.

10.4 Open Systems – Water Lubricated Shafts: Frequency of surveys

10.4.1 Survey in accordance with TS Method 4 at intervals of five years is applicable to any of the following:

(a) Single shaft operating in fresh water only;
(b) Single shaft provided with approved adequate means of protection against corrosion or fabricated from corrosion-resistant material;
(c) Multiple shaft arrangements.

10.4.2 Single shaft configurations other than listed above are to be surveyed every three years in accordance with TS Method 4.

10.4.3 For shafts subject to five-yearly surveys with keyless connections, at the Surveyor's discretion removal of the propeller and NDE of the shaft taper, as required by TS Method 4, need only be carried out every 15 years, subject to a satisfactory visual inspection of all accessible parts of the shafting system at the intervening surveys.

10.4.4 For surveys completed within three months before the shaft survey due date, the next survey period will start from the shaft survey due date.

10.4.5 At the discretion of the Classification Committee, consideration may be given to accept special arrangements to monitor the condition of the screwshaft, bearings, sealing devices and the sterntube lubricant system so as to allow an extension to the interval between withdrawals of the Screwshaft required by TS Method 4. This is subject to the shaft being provided with approved adequate means of protection against corrosion or being fabricated from corrosion-resistant material.

10.4.6 *See* Summary of Survey Intervals and Extensions for open systems in *Table 4.10.2 Summary of Survey Intervals and Extensions – Open systems*.

10.5 Survey extensions

10.5.1 For all types of propeller connections, consideration can be given at the discretion of the Classification Committee to an extension of the interval between two consecutive surveys after the execution of an extension survey as follows:

(a) Extension up to a maximum of 2,5 years: Only permitted for closed systems. No more than one extension can be considered. No further extension, of other type, can be considered.
(b) Extension up to a maximum of one year: Two consecutive ‘one year extensions’ can be considered. Where an additional extension is agreed the requirements of the ‘2,5 year extension’ are to be carried out and the shaft survey due date, prior to the previous extension(s), is extended for a maximum of 2,5 years.
(c) Extension up to a maximum of three months: One ‘three month extension’ can be considered. In the event an additional extension is agreed the requirements of the “one year extension” or ‘2,5 years extension’ are to be carried out and the shaft survey due date, prior to the previous extension, is extended for a maximum of one year or 2,5 years.

10.5.2 If the extension survey is carried out within one month of the shaft survey due date then the extension will take effect from the shaft survey due date.

10.5.3 If the extension survey is carried out more than one month prior to the shaft survey due date, then the period of extension will take effect from the date on which the extension survey was completed.

Table 4.10.1 Summary of Survey Intervals and Extensions – Closed systems

Oil Lubricated			
	Flanged Propeller Coupling	Keyless Propeller Coupling	Keyed Propeller Coupling (*see* Note b)
Every 5 years (*see* Note a)	TS Method 1 or TS Method 2 or TS Method 3	TS Method 1 or TS Method 2 or TS Method 3 (*see* Note c)	TS Method 1 or TS Method 2
Extension 2,5 years	Yes (*see* Note d)	Yes (*see* Note d)	Yes (*see* Note d)
Extension 1 year	Yes (*see* Note e)	Yes (*see* Note e)	Yes (*see* Note e)
Extension 3 months	Yes (*see* Note f)	Yes (*see* Note f)	Yes (*see* Note f)
Closed Loop System Fresh Water Lubricated			
	Flanged Propeller Coupling	Keyless Propeller Coupling	Keyed Propeller Coupling (*see* Note b)
Every 5 years (*see* Note a)	TS Method 1 (*see* Note g) or TS Method 2 or TS Method 3	TS Method 1 (*see* Note g) or TS Method 2 or TS Method 3	TS Method 1 (*see* Note g) or TS Method 2
Extension 2,5 years	Yes (*see* Note d)	Yes (*see* Note d)	Yes (*see* Note d)
Extension 1 year	Yes (*see* Note e)	Yes (*see* Note e)	Yes (*see* Note e)
Extension 3 months	Yes (*see* Note f)	Yes (*see* Note f)	Yes (*see* Note f)

General notes:

For surveys (TS Method 1, or TS Method 2, or TS Method 3) completed within 3 months before the shaft survey due date, the next period will start from the shaft survey due date.

If the extension survey is carried out within 1 month of the shaft survey due date then the extension will take effect from the shaft survey due date. If the extension survey is carried out more than 1 month prior to the shaft survey due date, then the period of extension counts from the date when the extension survey was completed.

Notes:

Note a. Unless an Extension (Extension 2,5 years, Extension 1 year, Extension 3 months) is applied in between.

Note b. TS Method 3 not allowed.

Note c. The maximum interval between two surveys carried out according to TS Method 1 or TS Method 2 shall not exceed 15 years, except in the case when one extension for no more than 3 months is agreed.

Note d. No more than one extension can be considered. No further extension of other type can be considered.

Note e. Two consecutive extensions can be considered. Where an additional extension is agreed the requirements of the '2,5 year extension' are to be carried out and the shaft survey due date, prior to the previous extension(s), is extended for a maximum of 2,5 years.

Note f. Extension up to a maximum of 3 months: One '3 month extension' can be considered. In the event an additional extension is agreed the requirements of the '1 year extension' or '2,5 years extension' are to be carried out and the shaft survey due date, prior to the previous extension, is extended for a maximum of 1 year or 2,5 years.

Note g. The maximum interval between two surveys carried out according to TS Method 1 shall not be more than 15 years, except in the case when one extension for no more than 3 months is agreed.

Table 4.10.2 Summary of Survey Intervals and Extensions – Open systems

• Single shaft operating exclusively in fresh water. • Single shaft provided with adequate means of corrosion protection, single corrosion resistant shaft. • All kinds of multiple shaft arrangements.		Other shaft configuration.	
	All kinds of Propeller Coupling (*see* Note d)		All kinds of Propeller Coupling (*see* Note d)
Every 5 years (*see* Note a)	TS Method 4	Every 3 years (*see* Note a)	TS Method 4
Extension 1 year	Yes (*see* Note b)	Extension 1 year	Yes (*see* Note b)
Extension 3 months	Yes (*see* Note c)	Extension 3 months	Yes (*see* Note c)

General notes:

For surveys (TS Method 4) completed within 3 months before the shaft survey due date, the next period will start from the shaft survey due date.

If the extension survey is carried out within 1 month of the shaft survey due date then the extension will take effect from the shaft survey due date. If the extension survey is carried out more than 1 month prior to the shaft survey due date, then the period of extension counts from the date when the extension survey was completed.

Notes:

Note a. Unless an Extension (Extension 1 year, Extension 3 months) is applied in between.

Note b. No more than one extension can be considered. No further extension, of other type, can be considered.

Note C. One extension can be considered. In the event an additional extension is agreed the requirements of the 1 year extension are to be carried out and the shaft survey due date prior to the previous extension is extended for a maximum of one year.

Note d. For keyless propeller connections the maximum interval between two consecutive dismantling and verifications of the shaft cone by means of non-destructive examination (NDE) shall not exceed 15 years.

10.6 Shaft Survey Methods

10.6.1 For the survey methods *see Table 4.10.3 Shaft Survey Methods* below.

Table 4.10.3 Shaft Survey Methods

	TS METHOD 1	TS METHOD 2	TS METHOD 3	TS METHOD 4
GENERAL				
Drawing the shaft and examining the entire shaft (including liners, corrosion protection system and stress reducing features, where provided), sealing system and bearings	X			X
SHAFT				
Visual examination of all accessible parts of the shafting system *in situ*		X	X	
For keyed and keyless propeller connections, removing the propeller to expose the forward end of the taper	X	X		X
For keyed and keyless propeller connections, perform a non-destructive examination (NDE) by an approved surface crack-detection method around the after end of the cylindrical part of the shaft and the forward one-third of the shaft cone, including the keyway with the key removed (if fitted); for shafts provided with liners the NDE shall be extended to the after edge of the liner	X	X		X
For flanged connections, whenever the coupling bolts of any type of flange-connected shaft are removed or the flange radius is made accessible in connection with overhaul, repairs or when deemed necessary by the Surveyor, the coupling bolts and flange radius are to be examined by means of an approved surface crack detection method	X	X	X	X
Visual examination of all accessible parts of the shafting system following re-installation of the shaft	X			X
PROPELLER				
Examination of the propeller	X	X	X	X
Controllable pitch propellers, where fitted, are to be opened up and the working parts examined, together with the control gear. Propeller to be examined upon reassembly	X	X		X
Where a controllable pitch propeller is fitted, at least one of the blades is to be dismantled completely for examination of the working parts and the control gear. Propeller to be examined upon reassembly			X	
Examination of the propeller following re-installation	X	X		X
BEARING CLEARANCES				
Checking, recording and verification of bearing clearances	X			X
Recording the bearing weardown measurements after re-installation, if applicable	X			
Checking and recording the bearing weardown measurements		X	X	

SEALING SYSTEM				
Examine the inboard and outboard seals with shaft removed and following the re-installation of the shaft and propeller	X			X
Examine the inboard and outboard seals		X	X	
Examination of seal liner		X	X	
OTHERS				
Stationary supporting structure and any erosion protection inserts or doublers are to be examined in way of any propulsion devices	X	X	X	X
Verification of no unapproved repairs by grinding or welding of shaft and/or propeller	X	X	X	X
SERVICE RECORDS				
Review of service records		X	X	
Review of test records of Lubricating Oil Analysis (for oil lubricated shafts), or Fresh Water Sample Test (for closed system fresh water lubricated shafts)		X	X	
Oil Sample Examination (for oil lubricated shafts), or Fresh Water Sample Test (for closed system fresh water lubricated).		X	X	

10.7 Other systems

10.7.1 Directional propeller and podded propulsion units for main propulsion purposes, inclusive of the propellers, shafts, gearing, control gear and the primary electrical components including any control and protection devices, are to be surveyed at intervals not exceeding five years. They are to be dismantled if considered necessary and generally examined as far as practicable. Non-destructive examination is to be carried out as considered necessary by the Surveyor on blade/fin roots. Consideration may be given to condition monitoring schemes for determining the condition of the unit.

10.7.2 Dynamic positioning and/or thruster-assisted mooring and athwartship thrust propellers and shaftings are to be surveyed at intervals not exceeding five years. They are to be generally examined so far as possible in dry dock and tested under working conditions afloat for satisfactory operation. All accessible parts, including sealing, locking and bearing faces, and any other moving parts are to be examined. Non-destructive examination is to be carried out as considered necessary by the Surveyor on blade/fin roots. Consideration may be given to condition monitoring schemes for determining the condition of the unit.

10.7.3 Water jet units for main propulsion purposes, including the impeller, casing, shaft, shaft seal, shaft bearing, inlet and outlet channels, steering nozzle, reversing arrangements, and control gear are to be surveyed at intervals not exceeding five years, provided the impeller shafts are made of approved corrosion-resistant material or have approved equivalent arrangements. They are to be generally examined so far as practicable.

10.7.4 Stationary supporting structure and any erosion protection inserts or doublers are to be examined in way of any propulsion devices.

10.8 Alternative arrangements

10.8.1 The Classification Committee will be prepared to give consideration to the circumstances of any special case upon application by the Owner, where the level of safety achieved is equivalent to that obtained by the survey methods described in this Section.

Section 11
Screwshafts, tube shafts, propellers and water jet units

11.1 Applicability

11.1.1 The requirements of this Section are only applicable to the first screwshaft survey on or after 1 January 2016 for yachts delivered before 1 January 2016. For subsequent screwshaft surveys, *see Pt 1, Ch 4, 10 Screwshafts, tube shafts, propellers and water jet units*.

11.1.2 For screwshaft survey requirements on yachts delivered on or after 1 January 2016, *see Pt 1, Ch 4, 10 Screwshafts, tube shafts, propellers and water jet units*.

11.2 Frequency of surveys

11.2.1 Shafts with keyed propeller attachments and fitted with continuous liners or approved oil glands, or made of approved corrosion resistant materials, are to be surveyed at intervals of five years when the keyway complies fully with the present Rules.

11.2.2 Shafts having keyless type propeller attachments are to be surveyed at intervals of five years provided they are fitted with approved oil glands or are made of approved corrosion resistant materials.

11.2.3 Shafts having solid coupling flanges at the after end are to be surveyed at intervals of five years provided they are fitted with approved oil glands or are made of approved corrosion resistant materials.

11.2.4 All other shafts not covered by *Pt 1, Ch 4, 11.2 Frequency of surveys 11.2.1* are to be surveyed at intervals of $2^1/_2$ years.

11.2.5 Controllable pitch propellers for main propulsion purposes are to be surveyed at the same intervals as the screwshaft.

11.2.6 Directional propeller units for main propulsion purposes are to be surveyed at intervals not exceeding five years.

11.2.7 Water jet units for main propulsion purposes are to be surveyed at intervals not exceeding five years provided the impeller shafts are made of approved corrosion resistant material or have approved equivalent arrangements.

11.2.8 Athwartship thrust propellers and shaftings are to be surveyed at intervals not exceeding five years, *see Pt 1, Ch 4, 6.2 Complete Surveys 6.2.2*.

11.3 Normal surveys

11.3.1 All screwshafts are to be withdrawn for examination by LR's Surveyors at the intervals prescribed in *Pt 1, Ch 4, 11.2 Frequency of surveys 11.2.1*. The after end of the cylindrical part of the shaft and forward one third of the shaft cone, or fillet of the flange, is to be examined by a magnetic particle crack detection method. In the case of a keyed propeller attachment at least the forward one third of the shaft cone is to be examined with the key removed. Weardown is to be measured and the sterntube bearings, oil glands, propellers and fastenings are to be examined. Controllable pitch propellers where fitted are to be opened up and the working parts examined, together with the controlgear.

11.3.2 Directional propeller units are to be generally examined so far as possible, including the propellers, shafts, gearing, controlgear and primary electrical components, inclusive of control and protection devices.

11.3.3 Water jet units are to be generally examined so far as possible, including the impeller, casing, shaft, shaft seal, shaft bearing, inlet and outlets channels, steering nozzle, reversing arrangements, and controlgear. On completion an operational test is to be carried out.

11.3.4 Stationary supporting structure and any erosion protection inserts or doublers are to be examined in way of any propulsion devices.

11.4 Screwshaft Condition Monitoring (SCM)

11.4.1 Where oil lubricated shafts with approved oil glands are fitted or where approved water lubricated sternbush bearings are fitted, and the Owner has complied with the requirements of *Pt 1, Ch 4, 11.4 Screwshaft Condition Monitoring (SCM) 11.4.2* or *Pt 1, Ch 4, 11.4 Screwshaft Condition Monitoring (SCM) 11.4.3*, the ShipRight descriptive note **SCM** (Screwshaft Condition Monitoring) may be entered in column 6 of the *Register Book*.

11.4.2 Oil lubricated bearings:

(a) Lubricating oil analysis to be carried out regularly at intervals not exceeding six months. The lubricating oil analysis documentation is to be available on board. Each analysis is to include the following minimum parameters:

- water content,
- chloride content,
- bearing material and metal particles content,
- oil ageing (resistance to oxidation).

(b) Oil samples are to be taken under service conditions and are to be representative of the oil within the sterntube.
(c) Oil consumption is to be recorded.
(d) Bearing temperatures are to be recorded (two temperature sensors or other approved arrangements are to be provided).
(e) Facilities are to be provided for measurement of bearing weardown.
(f) Oil glands are to be capable of being replaced without withdrawal of the screwshaft.

11.4.3 Water lubricated bearings:

(a) A means of monitoring and recording variations in the flow rate of lubricating water using two independent sensors is to be provided.
(b) A means of monitoring and recording variation in the shaft power transmission is to be provided.
(c) A maximum permitted weardown of the sternbush is to be submitted and approved wear monitoring equipment is to be fitted. The weardown allowance is to include both the absolute maximum allowable wear down and the weardown at which it is recommended to carry out an inspection and maintenance. An alignment analysis considering both the newly installed clearance and the proposed absolute maximum allowable weardown, demonstrating that the system will operate satisfactorily within these two limits, is to be submitted and approved.
(d) For open loop systems the manufacturer is to submit information regarding the required standard of lubricating water filtration and lubricating water filters or separators are to be fitted which are able to achieve this requirement:

- The lubricating water supply is to be fitted with continuous water sediment measuring or turbidity monitoring equipment with the results being recorded and retained on board and made available to LR on request; alternatively
- There is to be a LR approved extractive sampling and testing procedure with the records held on board and made available to LR on request.

Records of cleaning and replacement of lubrication filters/separators are to be maintained on board. The pumping and water filtration system is to be considered part of the continuous survey cycle and is to be subject to a Periodical Survey.

(e) Where a closed cycle water system is used, the pumping and water filtration systems are to be considered part of the continuous survey cycle and are to be subject to a Periodical Survey. Water analysis is to be carried out regularly at intervals not exceeding six months. Samples are to be taken under service conditions and are to be representative of the water circulating within the sterntube. Analysis results are to be retained on board and made available to LR on request.

The analysis is to include the following parameters:

(i) Chloride content;
(ii) Bearing material and metal particles content.

(f) The shaft is either to be constructed of corrosion resistant material or protected with an approved corrosion resistant protective liner or coating. Where a protective liner or coating is used, this shall meet the requirements of *Pt 11, Ch 2, 4.14 Corrosion resistant liners on shafts*, and a means of assessing the condition of this liner is to be submitted and approved.
(g) Glands are to be capable of being replaced without withdrawal of the screwshaft.
(h) There is to be a shaft starting/clutch engagement block to inhibit starting the shaft until lubricating water flow has been established. This is to only act as a starting block; low lubricating water flow after shaft start is to be alarm only with no shutdown.
(i) Alternative arrangements are subject to special consideration.

The means of monitoring and recording lubricating water flow and shaft power variation are to be submitted for approval.

11.4.4 For maintenance of the descriptive note **SCM** the records of all data collected in *Pt 1, Ch 4, 11.4 Screwshaft Condition Monitoring (SCM) 11.4.2* and *Pt 1, Ch 4, 11.4 Screwshaft Condition Monitoring (SCM) 11.4.3* are to be retained on board and audited by LR annually.

11.4.5 Where the requirements for the descriptive note **SCM** have been complied with, the screwshaft need not be withdrawn at surveys as required by *Pt 1, Ch 4, 11.3 Normal surveys 11.3.1* provided all condition monitoring data is found to be within permissible limits and all exposed areas of the shaft are examined by a magnetic particle crack detection method or an alternative

approved means for shafts with a protective liner (*Pt 1, Ch 4, 11.4 Screwshaft Condition Monitoring (SCM) 11.4.3.(f)*). The remaining requirements of *Pt 1, Ch 4, 11.3 Normal surveys 11.3.1* are to be complied with. Where the attending Surveyor considers that the data presented is not sufficient to determine the condition of the shaft, the shaft may be required to be withdrawn in accordance with *Pt 1, Ch 4, 11.3 Normal surveys 11.3.1*. For water lubricated bearings, the screwshaft is to be withdrawn for examination, as *Pt 1, Ch 4, 11.3 Normal surveys 11.3.1*, when the ship reaches 18 years from the date of build or the third Special Survey, whichever comes first.

11.5 Modified Survey

11.5.1 A Modified Survey may be accepted at alternate five-yearly surveys for shafts described in *Pt 1, Ch 4, 11.2 Frequency of surveys 11.2.1* provided they are fitted with oil lubricated bearings and approved oil glands, and also for those in *Pt 1, Ch 4, 11.2 Frequency of surveys 11.2.2* and *Pt 1, Ch 4, 11.2 Frequency of surveys 11.2.3*.

11.5.2 The Modified Survey is to consist of the partial withdrawal of the shaft, sufficient to ascertain the condition of the stern bearing and shaft in way. For keyless propellers or shafts with a solid flange connection to the propeller a visual examination to confirm the good condition of the sealing arrangements is to be made. The oil glands are to be capable of being replaced without removal of the propeller. The forward bearing and all accessible parts including the propeller connection to the shaft are to be examined as far as possible.

Wear-down is to be measured and found satisfactory. Where a controllable pitch propeller is fitted, at least one of the blades is to be dismantled complete for examination of the working parts and the controlgear.

11.5.3 For keyed propellers, the after end of the cylindrical part of the shaft and forward one third of the shaft cone is to be examined by a magnetic particle crack detection method, for which dismantling of the propeller and removal of the key will be required.

11.5.4 Where the descriptive note **SCM** has been assigned as described in *Pt 1, Ch 4, 11.4 Screwshaft Condition Monitoring (SCM) 11.4.1* and all data is found to be within permissible limits, partial withdrawal of the shaft may not be required. Where doubt exists regarding any of the above findings the shaft is to be withdrawn to permit an entire examination.

11.6 Partial Survey

11.6.1 For shafts where the Modified Survey is applicable, upon application by the Owner, the Committee will be prepared to give consideration to postponement of the survey for a maximum period of half the specified cycle provided a Partial Survey is held.

11.6.2 The Partial Survey is to consist of the propeller being backed off in any keyed shaft and the top half of the cone examined by an efficient crack detection method for which removal of the key will be required. Oil gland and seals are to be examined and dealt with as necessary. Weardown is to be measured and found satisfactory. Propeller and fastenings are to be examined.

11.6.3 The Committee will be prepared to give consideration to the circumstances of any special case upon application by the Owner.

■ *Section 12*
Surveys of unclassed machinery in existing classed yachts

12.1 General

12.1.1 The requirements of this survey are considered necessary in order to establish, so far as practicable, that the unclassed machinery installation does not constitute a hazard to the classed hull. The survey is applicable only to existing sailing yachts fitted with unclassed auxiliary propulsion engines not exceeding 37 KW.

12.1.2 At any time when unclassed machinery in an existing classed yacht is undergoing alteration and/or replacement, the requirements of *Pt 1, Ch 2, 4.4 Damages, repairs and alterations 4.4.6* are to be complied with.

12.2 Intermediate and Bottom Surveys

12.2.1 For Intermediate and Bottom Surveys, *see* Sections *Pt 1, Ch 4, 2 Intermediate Surveys - Hull and machinery requirements* and *Pt 1, Ch 4, 3 Bottom Surveys and In-Water Surveys - Hull and machinery requirements*.

12.3 Complete Surveys

12.3.1 At each Special Survey of the hull the requirements of *Pt 1, Ch 4, 12.2 Intermediate and Bottom Surveys 12.2.1* and the following are to be complied with:

(a) The bilge pumping system is to be examined and tested under working conditions.
(b) A general examination is to be made of the fuel tanks and fuel system with their valves, pipes and fittings, and of the engine exhaust system, piping and fittings.
(c) A general examination of the electrical equipment is to be made and, if considered necessary, a test of the insulation resistance is to be carried out in accordance with *Pt 1, Ch 4, 9.2 Complete Surveys 9.2.1*.
(d) The starting arrangements are to be examined.
(e) The screwshafts and tube shafts are to be withdrawn for examination.
(f) The main and essential auxiliary machinery is to be examined under full working conditions in accordance with *Pt 1, Ch 4, 8.1 Complete Surveys 8.1.4*.

■ *Section 13*
Classification of yachts not built under survey

13.1 General

13.1.1 When classification is desired for a yacht not built under the supervision of LR's Surveyors, application should be made to the Committee in writing.

13.1.2 Periodical Surveys of such yachts, when classed, are subsequently to be held as in the case of yachts built under survey.

13.1.3 Where classification is desired for a yacht which is classed by another recognised Society, special consideration will be given to the scope of the survey.

13.2 Hull and equipment

13.2.1 Plans showing the main scantlings and arrangements of the actual yacht together with any proposed alterations are to be submitted for approval.These should comprise plans of the midship section, longitudinal section and decks, and such other plans as may be requested. If plans cannot be obtained or prepared by the Owner, facilities are to be given for LR's Surveyor to obtain the necessary information from the yacht.

13.2.2 Particulars of the process of manufacture and the testing of the material of construction are to be supplied. The requirements for composite yachts will be specially considered.

13.2.3 The full requirements of Sections *Pt 1, Ch 4, 4 Special Survey - General - Hull requirements* and *Pt 1, Ch 4, 5 Special Survey - Thickness measurement requirements for steel yachts* are to be carried out as applicable. Yachts of recent construction will receive special consideration.

13.2.4 During the survey, the Surveyors are to satisfy themselves regarding the workmanship and verify the approved scantlings and arrangements. For this purpose, and also in order to ascertain the amount of any deterioration of steel yachts, parts of the structure will require to be gauged as necessary. Full particulars of the anchors, chain cables and equipment are to be submitted. For yachts to which *Pt 14, Ch 1 Steering Systems* applies, fire protection, detection and extinction are to be in accordance with the Rules.

13.2.5 When the full survey requirements indicated in *Pt 1, Ch 4, 13.2 Hull and equipment 13.2.3* and *Pt 1, Ch 4, 13.2 Hull and equipment 13.2.4* cannot be completed at one time, the Committee may consider granting an interim record for a limited period. The conditions regarding the completion of the survey will depend on the merits of each particular case, which should be submitted for consideration.

13.3 Machinery

13.3.1 To facilitate the survey, the following plans and particulars (plans of piping are to be diagrammatic), together with the particulars of the materials used in the construction of any boilers, air receivers and important forgings are to be submitted:

- Name of manufacturer of engine and gearbox including the manufacturer's type designation of engine and gearbox, together with the continuous shaft power of the engine at the crankshaft coupling with the revolutions per minute of crankshaft and propeller.
- General pumping arrangements, including air and sounding pipes (Builder's plan).
- Bilge, ballast and fuel oil pumping arrangements including the capacities of the pumps on bilge service.
- Arrangement and dimensions of any steam pipes.
- Arrangement of fuel oil pipes and fittings at settling and service tanks.
- Arrangement of fuel oil piping in connection with oil burning installations.
- Fuel oil overflow systems, where these are fitted.
- Arrangement of boiler feed systems.
- Fuel oil settling, service and other fuel oil tanks not forming part of the craft's structure.
- Boilers and economisers.
- Air receivers.
- Crank, thrust, intermediate and screw shafting.
- Details of water jet or directional propeller units, if fitted.
- Clutch and reversing gear with methods of control.
- Reduction gearing.
- Propeller (including spare propeller if supplied) where the diameter exceeds 1m.
- Electrical circuits.
- Arrangement of compressed air systems for main and auxiliary services.
- Arrangement of lubricating oil, other flammable liquids and cooling water systems for main and auxiliary services.
- Steering gear including control arrangement.
- Arrangement of exhaust system indicating materials, method of cooling, and if water spray injected, the method of draining.

13.3.2 Plans additional to those detailed in *Pt 1, Ch 4, 13.3 Machinery 13.3.1* are not to be submitted unless the machinery is of a novel or special character affecting classification.

13.3.3 Where remote and/or automatic controls are fitted to propulsion machinery and essential auxiliaries, a description of the scheme is to be submitted.

13.3.4 For new yachts and yachts which have been in service less than two years, calculations of the torsional vibration characteristics of the propelling machinery are to be submitted for consideration, as required for yachts constructed under Special Survey. For older yachts the circumstances will be specially considered in relation to their service record and type of machinery installed. Where calculations are not submitted, the Committee may require that the machinery certificate be endorsed to this effect. When desired by the Owner, the calculations and investigation of the torsional vibration characteristics of the machinery may be carried out by LR upon special request.

13.3.5 The main and auxiliary machinery, feed pipes, compressed air pipes and boilers are to be examined as required at Complete Surveys. Working pressures are to be determined from the actual scantlings in accordance with the Rules.

13.3.6 The screwshaft is to be drawn and examined.

13.3.7 Any steam pipes or oil burning installations are to be examined and tested as required by Pt 1, *Pt 1, Ch 3, 15 Boilers* or *Pt 1, Ch 3, 16 Steam pipes* of the *Rules and Regulations for the Classification of Ships*.

13.3.8 The bilge, ballast and fuel oil pumping arrangements are to be examined and amended, as necessary, to comply with the Rules.

13.3.9 The electrical equipment is to be examined as required at Complete Surveys.

13.3.10 The whole of the machinery, including essential controls, is to be tried under working conditions to the Surveyor's satisfaction.

Periodical Survey Regulations for Amphibious Air Cushion Vehicles (ACV)

■ *Section 1* General

1.1 Frequency of surveys

1.1.1 Except as amended at the discretion of the Committee, the periods between surveys are as follows:

(a) Annual Surveys are to be held within three months before or after each anniversary of the completion, commissioning or Special Survey.
(b) Intermediate Surveys are to be held instead of the second or third Annual Survey after completion, commissioning or Special Survey.
(c) Special Surveys (hull and machinery) are to be held at the fifth anniversary after completion, commissioning or previous Special Survey.

1.2 Machinery surveys

1.2.1 The manufacturer's approved operating and service instructions for the main and auxiliary power units, transmission systems, propellers and lift fans are to be incorporated into an approved planned maintenance scheme for the ACV.

1.2.2 Maintenance, overhaul or replacement will then normally be determined by the specified condition/performance monitoring limits and running hours.

1.2.3 It is a requirement of this arrangement that any significant defect, damage repair or alteration be reported to Lloyd's Register (hereinafter referred to as 'LR') without delay, *see also Pt 1, Ch 2, 1.1 General 1.1.7*.

1.3 Surveys for damage, repairs or alterations

1.3.1 At any time when an ACV is undergoing alterations or damage repairs, any exposed parts of the structure normally difficult to access are to be specially examined, e.g. if any part of the main or auxiliary machinery is removed for any reasons, the hull structure in way is to be carefully examined by the Surveyor.

1.3.2 All significant repairs, alterations, approved modifications and replacements are to be recorded in the ACV's Log Books in a manner that will enable their later identification by the Surveyors, *see also Pt 1, Ch 2, 4.4 Damages, repairs and alterations 4.4.1* and *Pt 1, Ch 2, 4.4 Damages, repairs and alterations 4.4.6*.

1.3.3 Trials are to be made on any craft which have been significantly modified, overhauled or repaired, prior to returning to service, to ensure to the Surveyor's satisfaction that the ACV has been returned in a satisfactory condition for its intended service.

1.4 Unscheduled surveys

1.4.1 In the event that LR has cause to believe that its Rules and Regulations are not being complied with, LR reserves the right to perform unscheduled surveys of the hull and machinery as well as the applicable statutory requirements whether or not the appropriate statutory certificate has been issued by LR.

1.5 Surveys for the issue of Convention Certificates

1.5.1 Surveys are to be held either by LR when so appointed or by the Exclusive Surveyors of a National Administration when so delegated by a Flag State.

Section 2
Annual Surveys - Hull and machinery requirements

2.1 General

2.1.1 Annual Surveys are to be held concurrently with any relevant statutory annual or other statutory surveys, wherever practicable.

2.1.2 The Surveyor is to audit the approved planned maintenance scheme. The records will be checked and the satisfactory operation of the scheme verified. Condition monitoring data will be reviewed and trends analysed.

2.1.3 The Surveyor is to examine the Log Book to verify that a proper record has been kept in respect of servicing, maintenance and overhaul requirements for those aspects not covered by the approved planned maintenance scheme.

2.1.4 Certification for replacement units/parts will be required.

2.2 Preparation

2.2.1 The ACV is to be slung or jacked up to permit a thorough inspection of all underside parts, fittings and attachments.

2.2.2 Panelling, floor coverings etc. need not be removed at these surveys, unless they are of portable type or unless the Surveyor has reason to suspect they may conceal significant damage.

2.3 Hull items

2.3.1 The Surveyor is to be satisfied as to the efficient condition of the following items:

(a) Bottom and side plating, any external stiffeners, and side walls or skirts, including flexible keels, if any.
(b) Weather doors, ventilators, windows and emergency or other hatches.
(c) Weather decks, houses, etc.
(d) Machinery casings and seats.
(e) Anchoring and mooring equipment when required by the Rules.
(f) Fire equipment including fire detection, alarm systems and means of escape , where the survey of such items is not covered by statutory certification.
(g) Where applicable, passenger seat foundations and cargo tie down points.
(h) Skirt attachment and operating mechanisms.
(i) Air propeller shroud structures.
(j) Side body attachments and supports (when fitted).
(k) Operation of ramps, and their closing and locking arrangements.
(l) The structural attachment and retention arrangements for external fuel tanks (when fitted).

2.4 Machinery items

2.4.1 The Surveyor is to be satisfied as to the efficient condition of the following items:

(a) Fuel tanks and associated fuel system with pumps, filters, etc.
(b) Lubricating oil tanks and associated lubricating system with coolers, pumps, filters, etc.
(c) The bilge pumping system.
(d) Machinery alarm arrangements.
(e) The electrical machinery, the switchgear and other electrical equipment are to be generally examined under operating conditions so far as practicable. The satisfactory operation of the emergency source of power, including the automatic controls as fitted, is to be verified.
(f) Hydraulic, electrical and pneumatic control systems, including steering, are to be examined under operating conditions.
(g) Engine starting arrangements.
(h) All drive belts, associated running surfaces and tension adjustment (where fitted).
(i) Air propellers, including (where fitted) hub assemblies, servos and actuating equipment of controllable pitch propellers.
(j) The overall operation of the machinery including propulsion and lift machinery. A machinery proving trial of short duration is to demonstrate to the Surveyor the satisfactory operation of the machinery.

Section 3
Intermediate Surveys - Hull and machinery requirements

3.1 General

3.1.1 The requirements of *Pt 1, Ch 5, 2 Annual Surveys - Hull and machinery requirements* are to be complied with.

3.2 Preparation

3.2.1 A sufficient amount of panelling, floor covering, insulation and paint etc. is to be removed to enable the Surveyors to satisfy themselves that all major structural items are in a satisfactory condition.

3.3 Examination and testing

3.3.1 Representative integral tanks and buoyancy spaces are to be examined as necessary to ensure that they continue to be in a satisfactory condition.

3.3.2 At the discretion of the Surveyor, tanks or buoyancy spaces may require to be tested to ensure that they continue to be tight.

Section 4
Special Surveys (Hull and machinery)

4.1 General

4.1.1 The requirements of Sections *Pt 1, Ch 5, 2 Annual Surveys - Hull and machinery requirements* and *Pt 1, Ch 5, 3 Intermediate Surveys - Hull and machinery requirements* are to be complied with.

4.2 Hull Surveys

4.2.1 All integral tanks and buoyancy spaces are to be examined and tested to ensure that they continue to be tight and in a satisfactory condition.

4.2.2 All other hull compartments are to be examined.

4.2.3 The anchoring and mooring equipment, when required by the Rules, is to be examined to ensure its efficiency, accessibility and readiness for use. Anchor cables or warps are to be ranged for examination.

4.3 Machinery Surveys

4.3.1 The main and essential auxiliary machinery is to be generally examined with particular attention given to safety devices, fastening arrangements and resilient mountings. A limited opening up, e.g. removal of inspection covers, should be undertaken in order that the Surveyor can confirm the satisfactory condition of these items.

4.3.2 Where not carried out as a regular monitoring procedure, lubricating oil analysis may be required.

4.3.3 Items that have not been overhauled as part of the approved planned maintenance scheme since installation, commissioning or the previous Special Survey may require to be opened up for examination.

4.3.4 The insulation resistance of the electrical equipment and connections is to be tested.

Section 5
Classification of ACVs not built under survey

5.1 General

5.1.1 The requirements for classification of an ACV not built under the supervision of LR's Surveyors are to be in accordance with the applicable sub-Sections of *Pt 1, Ch 3, 13 Classification of craft not built under survey*.

Contents

Section 1
Rules for the Manufacture Testing and Certification of Materials

1.1 Reference

Please see *Rules for the Manufacture, Testing and Certification of Materials, July 2021*

Contents

■ *Section 1* Rules application

1.1 General

1.1.1 The Rules apply to sea-going motor, sailing and auxiliary craft of normal form, proportions and speed, generally not exceeding a Rule length, L_R of 150 m.

1.2 Exceptions

1.2.1 Craft of unusual form, proportions or speed, or intended for the carriage of special cargoes, or for special or restricted service, not covered specifically by the Rules, will receive individual consideration based on the general standards of the Rules.

1.3 Loading

1.3.1 The Rules are framed on the understanding that craft will be properly loaded and handled; they do not, unless it is stated or implied in the class notation, provide for special distributions or concentrations of loading other than those included in the approved Loading Manual. The Committee may require additional strengthening to be fitted in any craft which, in their opinion, would otherwise be subjected to severe stresses due to particular features of the design, or where it is desired to make provision for exceptional load or ballast conditions.

1.4 Advisory services

1.4.1 The Rules do not cover certain technical characteristics, such as stability except as mentioned in *Pt 1, Ch 2, 1.1 General 1.1.11* and *Pt 1, Ch 2, 1.1 General 1.1.13*, trim, vibration, docking arrangements, etc. The Committee cannot assume responsibility for these matters but is willing to advise upon them on request.

■ *Section 2* Direct calculations

2.1 General

2.1.1 Direct calculations may be specifically required by the Rules or may be required for craft having novel design features, as defined in *Pt 3, Ch 1, 1.2 Exceptions*, or may be submitted in support of alternative arrangements and scantlings. Lloyd's Register (hereinafter referred to as 'LR') may, when requested, undertake calculations on behalf of designers and make recommendations in regard to suitability of any required model tests.

2.1.2 Where model testing is undertaken to complement direct calculations the following details would normally be required to be submitted: Schedule of tests, details of test equipment, input data, analysis and calibration procedure together with tabulated and plotted output.

2.2 Submission of direct calculations

2.2.1 In cases where direct calculations have been carried out, the following supporting information should be submitted as applicable:

(a) Reference to the direct calculation procedure and technical program used.
(b) A description of the structural modelling.
(c) A summary of analysis parameters including properties and boundary conditions.
(d) Details of the loading conditions and the means of applying loads.
(e) A comprehensive summary of calculation results. Sample calculations should be submitted where appropriate.

2.2.2 In general, submission of large volumes of input and output data associated with such programs as finite element analysis will not be necessary.

2.2.3 The responsibility for error free specification and input of program data and the subsequent correct transposal of output rests with the Builder.

2.3 Global hull strength

2.3.1 Longitudinal strength calculations are to be submitted for all craft with a Rule length, L_R, exceeding that specified in *Pt 6, Ch 6 Hull Girder Strength*, *Pt 7, Ch 6 Hull Girder Strength* and *Pt 8, Ch 6 Hull Girder Strength*, for steel, aluminium alloy and composite respectively, covering the range of load and ballast conditions proposed, in order to determine the required hull girder strength. Still water bending moments and shear forces are to be calculated for both departure and arrival conditions and for any special mid-voyage conditions caused by changes in ballast distribution.

2.3.2 Where the Rule length, L_R, does not exceed that indicated in *Pt 3, Ch 1, 2.3 Global hull strength 2.3.1*, longitudinal strength calculations may be required at LR's discretion, dependent upon craft proportions, the proposed loading, structural configuration and material of construction.

■ *Section 3*
Equivalents

3.1 Alternative arrangements and scantlings

3.1.1 In addition to cases where direct calculations are specifically required by the Rules, LR will consider alternative arrangements and scantlings which have been derived by direct calculations in lieu of specific Rule requirements. All direct calculations are to be submitted for examination.

3.1.2 Where calculation procedures other than those available from software published by LR are employed, supporting documentation is to be submitted for appraisal and this is to include details of the following:

- calculation methods;
- assumptions and references;
- loading;
- structural modelling;
- design criteria and their derivation, e.g. permissible stresses;
- factors of safety against plate panel instability, etc.

3.1.3 LR will be ready to consider the use of Builder's programs for direct calculations in the following cases:

(a) Where it can be established that the program has previously been satisfactorily used to perform a direct calculation similar to that now submitted.
(b) Where sufficient information and evidence of satisfactory performance is submitted to substantiate the validity of the computation performed by the program.

3.1.4 Alternative arrangements or fittings which are considered to be equivalent to the Rule requirements will be accepted.

3.1.5 Where no special reference is made in this Part to specific requirements, the construction is to be efficient for the intended purpose and to conform to good practice.

3.1.6 Where items are of a novel or unconventional design or manufacture, it is the responsibility of the Builder to demonstrate their suitability and equivalence to the Rule requirements.

3.1.7 Alternative arrangements which are in accordance with the requirements of a National Authority may be accepted as equivalent to the requirements of this Part of the Rules.

■ *Section 4* National and International Regulations

4.1 International Conventions

4.1.1 The Committee, when authorised, will act on behalf of Governments and, if requested, LR will certify compliance in respect of National and International statutory safety and other requirements for passenger and cargo craft.

4.1.2 In satisfying the Load Line Convention, the general structural strength of the craft is required to be sufficient for the draught corresponding to the freeboards to be assigned. Craft built and maintained in accordance with LR's Rules and Regulations possess adequate strength to satisfy the Load Line Convention. However, some National Authorities may, in addition, require to be supplied with calculations of bending moments and shear forces for certain conditions of loading.

4.2 International Association of Classification Societies (IACS)

4.2.1 Where applicable, the Rules take into account unified requirements and interpretations established by IACS.

4.3 International Maritime Organisation (IMO)

4.3.1 Attention is drawn to the fact that Codes of Practice issued by IMO contain requirements which are outside the scope of classification as defined in these Rules and Regulations.

■ *Section 5* Information required

5.1 General

5.1.1 The categories and lists of information required are given in *Pt 3, Ch 1, 5.2 Submission of plans and data*.

5.1.2 Plans are generally to be submitted in triplicate, but one copy only is necessary for supporting documents and calculations.

5.1.3 Plans are to contain all necessary information to fully define the structure, including construction details, equipment and systems as appropriate.

5.1.4 Additional requirements for individual craft types are given in subsequent Chapters.

5.2 Submission of plans and data

5.2.1 Plans and data required to be submitted are indicated in *Pt 6 Hull Construction in Steel*, *Pt 7 Hull Construction in Aluminium* and *Pt 8 Hull Construction in Composite* for steel, aluminium alloy and composite construction respectively, as appropriate.

5.2.2 Where an ***IWS** (In-Water Survey) notation is to be assigned, *see Pt 1, Ch 2, 3.8 Other hull notations 3.8.2*, plans and information covering the following items are to be submitted:

- Details showing how rudder pintle and bush clearances are to be measured and how the security of the pintles in their sockets are to be verified with the craft afloat.

- Details showing how stern bush clearances are to be measured with the craft afloat.
- Details of high resistance paint, for information only.

5.3 Standard designs

5.3.1 Where a craft is a standard design produced in several versions, the plans and data are to clearly define the differences between each version.

5.3.2 Where the craft is a Builder's standard design to be built from previously approved plans and data, a schedule of applicable plans, etc. is to accompany the Request for Survey. Plans of any proposed modifications and changes to the previously approved plans are to be submitted for approval prior to the commencement of any work.

5.3.3 Plan approval of standard designs is only valid so long as no applicable Rule changes take place. When the Rules are amended, the plans for standard types are to be submitted for re-approval.

5.4 Plans and data to be supplied to the craft

5.4.1 To facilitate the ordering of materials for repairs, plans are to be carried in the craft indicating the disposition and grades (other than Grade A) of hull structural steel, the extent and location of higher tensile steel together with details of specification and mechanical properties, and any recommendations for welding, working and treatment of these steels.

5.4.2 Similar information is to be provided when aluminium alloy, fibre composite or other materials are used in the hull construction.

5.4.3 A copy of the final Loading Manual, (where applicable) when approved, and details of the loadings applicable to approved decks, hatch covers and inner bottom are to be placed on board the craft.

5.4.4 Details of any corrosion control system fitted are to be placed on board the craft.

5.4.5 Copies of main scantling plans are to be placed on board.

5.4.6 Electrical cables schedule of watertight penetrations (e.g. cable transit seal systems register).

5.4.7 Where an ***IWS** (In-water Survey) notation is to be assigned, approved plans and information covering the items detailed in *Pt 3, Ch 1, 5.2 Submission of plans and data 5.2.2* are to be placed on board.

5.5 Fire protection, detection and extinction

5.5.1 For information and plans required, *see Pt 17 Fire Protection, Detection and Extinction*.

■ *Section 6* Definitions

6.1 General

6.1.1 The following definitions apply except where they are inappropriate or where specifically defined otherwise.

6.2 Principal particulars

6.2.1 **Rule length**, L_R, is the distance, in metres, on the summer load waterline from the forward side of the stem to the after side of the rudder post or to the centre of the rudder stock if there is no rudder post. L_R is to be not less than 96 per cent, and need not be greater than 97 per cent, of the extreme length on the summer load waterline. In craft without rudders, the Rule length, L_R, is to be taken as 97 per cent of the extreme length on the summer load waterline. In craft with unusual stem or stern arrangements the Rule length, L_R, will be specially considered.

6.2.2 **Length between perpendiculars**, L_{pp}, is the distance, in metres, on the summer load waterline from the fore side of the stem to the after side of the rudder post, or to the centre of the rudder stock if there is no rudder post. In craft with unusual stern arrangements the length, L_{pp}, will be specially considered. The forward perpendicular, F.P., is the perpendicular at the intersection of the summer load waterline with the fore side of the stem. The after perpendicular, A.P., is the perpendicular at the intersection of the summer load waterline with the after side of the rudder post or to the centre of the rudder stock for craft without a rudder post.

6.2.3 **Load line length**, L_{L}, is to be taken as 96 per cent of the total length on a waterline at 85 per cent of the least moulded depth measured from the top of the keel, or as the length from the fore side of the stem to the axis of the rudder stock on that waterline, if that is greater. In craft designed with a rake of keel, the waterline on which this length is measured is to be parallel to the designed waterline. The length L_{L} is to be measured in metres.

6.2.4 **Length of the hull**, L_{H}, is the distance, in metres, measured parallel to the static load waterline from the foremost part of the stem to the aftermost part of the stern or transom, including all structural and integral parts of the craft, such as wooden, plastic or metal stems or sterns, bulwarks and hull/deck joints and excluding removable parts that can be detached in a non-destructive manner and without affecting the structural integrity of the craft, e.g. spars, bowsprits, pulpits at either end of the craft, stemhead fittings, rudders, outdrives, outboard motors and their mounting brackets and plates, diving platforms, boarding platforms, rubbing strakes, fenders and other projections. Detachable parts of the hull acting as hydrostatic or dynamic support to the craft when at rest or underway are not excluded. In case of multi-hull craft, the length of each hull shall be measured individually and L_H shall be taken as the longest of the individual measurements.

6.2.5 **Length waterline**, L_{WL}, is the distance, in metres, measured on the static load waterline from the foreside of the stem to the after side of the stern or transom.

6.2.6 **Amidships** is to be taken as the middle of the Rule length, L_{R}, measuring from the forward side of the stem.

6.2.7 **Breadth**, B, is the greatest moulded breadth, in metres, or, for craft of composite construction, the extreme breadth excluding rubbing strakes or other projections. For multi-hull craft it is to be taken as the sum of the breadths of the individual hulls.

6.2.8 **Depth**, D, is measured, in metres, at the middle of the Rule length, L_{R}, from top of keel to top of the deck beam at side on the uppermost continuous deck, or as defined in appropriate Chapters. When a rounded gunwale is arranged, the depth D is to be measured to the continuation of the moulded deck line at side.

6.2.9 **Draught**, T, is the summer draught, in metres, measured from top of keel. Where a deeper ‘scantling draught’ has been specified by the designer, this is to be used instead.

6.2.10 **Block coefficient**, C_{b}, is the moulded block coefficient at draught T corresponding to summer load waterline, based on Rule length $L_{R}$and moulded breadth B, as follows:

$$C_{\mathrm{b}} = \frac{\text{mouldeddisplacement}\left(\mathrm{m}^3\right)\text{ at draught } T}{L_{\mathrm{R}}BT}$$

6.3 Freeboard deck

6.3.1 The freeboard deck is normally the uppermost complete deck exposed to weather and sea, which has permanent means of closing all openings in the weather part thereof, and below which all openings in the sides of the craft are fitted with permanent means of watertight closing. It is the deck from which the freeboard is measured.

6.4 Bulkhead deck

6.4.1 Bulkhead deck is the uppermost deck up to which the transverse watertight bulkheads are carried.

6.5 Strength deck

6.5.1 Strength deck is normally the uppermost continuous deck. Other decks may be considered as the strength deck provided that such decks are structurally effective.

6.6 Weather deck

6.6.1 A weather deck is a deck which is exposed to sea and weather loads.

6.6.2 The weather deck is the lowest continuous deck exposed to sea and weather loads, and is not to be taken lower than the bulkhead deck for the determination of the requirements for closing appliances from *Pt 3, Ch 4 Closing Arrangements and Outfit*.

6.7 Wet deck

6.7.1 A wet deck is the lower most exposed surface of the cross-deck structure, connecting the hulls of a multi-hull craft.

6.8 Weathertight

6.8.1 A closing appliance is considered weathertight if it is designed to prevent the passage of water into the craft in any sea conditions.

6.8.2 Generally, all openings in the freeboard deck and in enclosed superstructures are to be provided with weathertight closing appliances.

6.9 Watertight

6.9.1 A closing appliance is considered watertight if it is designed to prevent the passage of water in either direction under a head of water for which the surrounding structure is designed.

6.9.2 Generally, all openings below the freeboard deck in the outer shell/envelope (and in main bulkheads) are to be fitted with permanent means of watertight closing.

6.10 Position 1 and Position 2

6.10.1 For the purpose of Load Line Conditions of Assignment, there are two basic positions of hatchways, doorways and ventilators defined as follows (*see also Figure 1.6.1 Position 1 and Position 2*):

Position 1:

- Exposed decks located abaft the forward 0,25 of the load line length, L_L, and less than one standard superstructure height above the freeboard deck.
- Exposed decks situated within the forward 0,25 of the load line length, L_L, and located less than two standard heights of superstructure above the freeboard deck.

Position 2:

- Exposed decks situated abaft the forward 0,25 of the load line length, L_L, and located at least one standard height of superstructure, but less than two standard heights of superstructure, above the freeboard deck.
- Exposed decks situated within the forward 0,25 of the load line length, L_L, and located at least two standard heights of superstructure, but less than three standard heights of superstructure, above the freeboard deck.

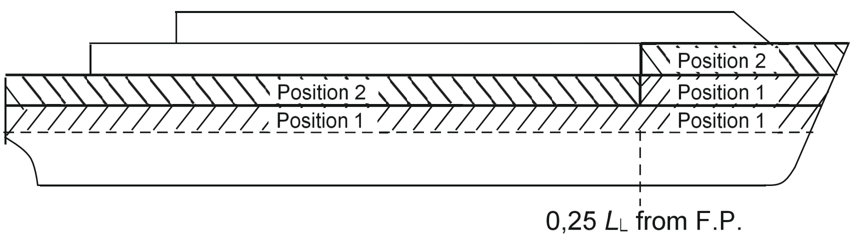


Figure 1.6.1 Position 1 and Position 2

6.11 Reference system

6.11.1 For hull reference purposes, the craft is divided into 21 equally spaced stations where Station 0 is the after perpendicular, Station 20 is the forward perpendicular, and Station 10 is mid-L_{pp}.

6.12 Co-ordinate system

6.12.1 Unless otherwise stated, the co-ordinate system is as shown in *Figure 1.6.2 Co-ordinate system*, that is, a right-hand co-ordinate system with the X axis positive forward, the Y axis positive to port and the Z axis positive upwards. Angular motions are considered positive in a clockwise direction about the X, Y or Z axes.

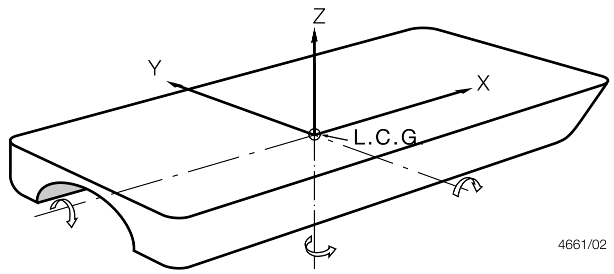


Figure 1.6.2 Co-ordinate system

6.13 Superstructure

6.13.1 A superstructure is defined as a decked structure on the freeboard deck, extending from side to side of the craft, or with the side plating being less than four per cent of the breadth, *B*, inboard of the shell plating.

6.13.2 An enclosed superstructure is a superstructure with:

(a) Enclosing bulkheads of efficient construction;
(b) Access openings, if any, in these bulkheads fitted with doors complying with the requirements of *Pt 3, Ch 4, 6.5 Companionways, doors and accesses on weather decks*;
(c) All other openings in sides or ends of the superstructure fitted with efficient weathertight means of closing.

6.13.3 The standard height of superstructure for L_L of 75 m or less is to be taken as 1,8 m, and for L_L of 125 m or greater is to be taken as 2,3 m. Intermediate values are to be determined by linear interpolation.

6.14 Deckhouse

6.14.1 A deckhouse is in general defined as a decked structure on or above the freeboard deck with side plating being four per cent or more of the breadth, *B*, inboard of the shell plating.

■ *Section 7*
Inspection, workmanship and testing procedures

7.1 General

7.1.1 The minimum requirements in respect of inspection, workmanship and testing are contained within *Pt 6, Ch 2 Construction Procedures*, *Pt 7, Ch 2 Construction Procedures* and *Pt 8, Ch 2 Construction Procedures*, of the Rules for craft constructed in steel, aluminium alloy and composite respectively.

7.2 Construction standards

7.2.1 Construction standards for all materials are to be in accordance with National Standards or these Rules whichever are the higher.

7.2.2 The design requirements for welding and structural detail are to be found in *Pt 6 Hull Construction in Steel* and *Pt 6 Hull Construction in Steel* of the Rules for craft constructed in steel and aluminium alloy respectively.

7.2.3 The design requirements for the bonding of all structural detail of composite materials are contained in *Pt 8 Hull Construction in Composite*.

7.3 Testing procedures

7.3.1 **Definitions.** For the purpose of these procedures the following definitions apply:

(a) **Protective coating** is the coating system applied to protect the structure from corrosion. This excludes the prefabrication primer.

(b) **Structural testing** is a hydrostatic test carried out to demonstrate the tightness of the tanks and the structural adequacy of the design. Where practical limitations prevail and hydrostatic testing is not feasible, hydropneumatic testing, *see* (e), may be carried out instead.

(c) **Leak testing** is an air or other medium test carried out to demonstrate the tightness of the structure.

(d) **Hose testing** is carried out to demonstrate the tightness of structural items not subjected to hydrostatic or leak testing, and other components which contribute to the watertight or weathertight integrity of the hull.

(e) **Hydropneumatic testing** is a combination of hydrostatic and air testing, consisting of filling the tank with water and applying an additional air pressure. The conditions are to simulate, as far as practicable, the actual loading of the tank and in no case is the air pressure to be less than given in *Pt 3, Ch 1, 7.3 Testing procedures 7.3.4*.

7.3.2 **Application.** The testing requirements for tanks, including independent tanks, watertight and weathertight compartments, are listed in *Table 1.7.1 Testing requirements*. Tests are to be carried out in the presence of the Surveyor at a stage sufficiently close to completion such that the strength and tightness are not subsequently impaired.

7.3.3 **Structural testing.** The attachment of fittings to oiltight surfaces is to be completed before tanks are structurally tested. Where it is intended to carry out structural tests after the protective coating has been applied welds are generally to be leak tested prior to the coating application.

For welds other than manual and automatic erection welds, manual fillet welds on tank boundaries and manual penetration welds, the leak test may be waived provided that careful visual inspection is carried out, to the satisfaction of the Surveyor, before the coating is applied. The cause of any discolouration or disturbance of the coating is to be ascertained, and any deficiencies repaired.

7.3.4 **Leak testing.** This is carried out by applying an efficient indicating liquid (e.g. soapy water solution) to the weld or outfitting penetration being tested, while the tank or compartment is subject to an air pressure of at least 0,15 bar (0,15 kgf/cm^2).

It is recommended that the air pressure be raised to 0,2 bar (0,2 kgf/cm^2) and kept at this level for about one hour to reach a stabilised state, with a minimum number of personnel in the vicinity, and then lowered to the test pressure prior to inspection. A U-tube filled with water to a height corresponding to the test pressure is to be fitted for verification and to avoid overpressure. The U-tube is to have a cross-section larger than that of the air supply pipe. In addition, the test pressure is to be verified by means of a pressure gauge, or alternative equivalent system.

For tanks constructed of steel or aluminium, leak testing is to be carried out, prior to the application of a protective coating, on all fillet welds and erection welds on tank boundaries, excepting welds made by automatic processes and on all outfitting penetrations.

Selected locations of automatic erection welds and pre-erection manual or automatic welds may also be required to be tested before coating, at the discretion of the Surveyor, taking account of the quality control procedures of the shipyard. Where exempt from this requirement, leak testing may be carried out after the protective coating has been applied, provided that the welds have been carefully inspected to the satisfaction of the Surveyor.

Table 1.7.1 Testing requirements

Item to be tested	Testing procedure	Testing requirement
Double bottom tanks	Structural(1)	The greater of: - head of water up to the top of the overflow - head of water up to the margin line - head of water representing the maximum pressure experienced in service
Cofferdams	Structural(1)	The greater of: - head of water up to the top of the overflow - 1,8m head of water above the highest point of tank(4)
Forepeak and aft peak used as tank(3)	Structural	
Tank bulkheads	Structural(1)	The greater of:

Deep tanks	Structural(1)	- head of water up to the top of the overflow
Scupper and discharge pipes in way of tanks	Structural(1)	-1,8m head of water above the highest point of tank(4) - setting pressure of the safety valves, where relevant
Double plate rudders	Leak, *see* Note 5	*See Pt 3, Ch 1, 7.3 Testing procedures 7.3.4*
Watertight doors (below freeboard or bulkhead deck) and watertight hatches when fitted in place	Hose(2)	*See Pt 3, Ch 1, 7.3 Testing procedures 7.3.5*
Watertight doors (below freeboard or bulkhead deck) when fitted in place	Hose(6)	
Weathertight hatch covers and closing appliances	Hose(8)	
Fore peak not used as tank	Hose(2)	
Shell doors when fitted in place	Hose(7)	
Chain locker	Structural(9)	The greater of: • head of water up to the top of the spurling pipe • head of water up to the exposed weather deck(9)
Separate fuel oil tanks	Structural	Head of water representing the maximum pressure which could be experienced in service, but not less than 3,5m
After peak not used as tank	Leak	*See Pt 3, Ch 1, 7.3 Testing procedures 7.3.4*

Note 1. Leak or hydropneumatic testing may be accepted, provided that at least one tank of each type is structurally tested, to be selected in connection with the approval of the design. (*See also Pt 3, Ch 1, 7.3 Testing procedures 7.3.9* and *Pt 3, Ch 1, 7.3 Testing procedures 7.3.10*).

Note 2. When hose testing cannot be performed without damaging possible outfittings already installed, it may be replaced by a careful visual inspection of all the crossings and welded joints. Where necessary, dye penetrant test or ultrasonic leak test may be required.

Note 3. Testing of the aft peak is to be carried out after the sterntube has been fitted.

Note 4. The highest point of the tank is generally to exclude hatchways. In holds for liquid cargo or ballast with large hatch openings, the highest point of the tank is to be taken to the top of the hatch.

Note 5. If leak or hydropneumatic testing is carried out, arrangements are to be made to ensure that no pressure in excess of 0,30 bar (0,30 kgf/cm^2) can be applied.

Note 6. *See also* SOLAS Chapter II-1 *Regulation 16 - Construction and initial tests of watertight closures*. Where the door or hatch has been subject to the full hydrostatic test before installation, the hose test may be replaced by careful visual examination.

Note 7. For shell doors providing watertight closure, watertightness is to be demonstrated through prototype testing of the seal system before installation. The testing procedure is to be agreed with LR.

Note 8. On yachts, as defined in Chapter 1, a minor seepage of water up to 0,5 litres within 3 minutes, through the door, is permissible. Weathertight hatch covers and closing appliances to be tested are those on the weatherdeck in the forward 0,25L_R and those specified in *Pt 3, Ch 4, 6.5 Companionways, doors and accesses on weather decks 6.5.2.(b)* and *Pt 3, Ch 4, 6.5 Companionways, doors and accesses on weather decks 6.5.2.(c)* of the Rules for Special Service Craft.

Note 9. For yachts up to 500GT, the chain locker arrangement fitted forward of the collision bulkhead may be accepted, based on the structural plans and leak testing.

7.3.5 **Hose testing.** This is to be carried out at a maximum distance of 1,5 m with a hose pressure not less than 2,0 bar (2,0 kgf /cm^2). The nozzle diameter is not to be less than 12 mm. The jet is to be targeted directly onto the weld or seal being tested.

7.3.6 **Hydropneumatic testing.** When this is performed, the safety precautions identified in *Pt 3, Ch 1, 7.3 Testing procedures 7.3.4* are to be followed.

7.3.7 For tanks of composite construction, leak testing is to be carried out to air pressures as indicated in *Pt 3, Ch 1, 7.3 Testing procedures 7.3.4*.

7.3.8 Structural testing may be carried out afloat where testing using water is undesirable in dry-dock or on the building berth. The testing afloat is to be carried out by separately filling each tank and cofferdam to the test head given in *Table 1.7.1 Testing*

requirements. Alternate tanks and cofferdams may be filled to the test head and the bottom and lower side shell in the intermediate empty tanks and cofferdams and all boundaries are to be examined and the remainder of the bottom and lower side shell and boundaries examined when the water is transferred to the remaining tanks.

7.3.9 Where permitted by *Table 1.7.1 Testing requirements*, complete structural testing may be replaced by a combination of leak and structural testing, as follows. The leak test is generally to be carried out on each tank while the craft is in dry-dock or on the building berth.

(a) Double bottom tanks and cofferdams may be leak tested on the berth, and structural tests carried out afloat.
(b) All deep tanks are to be structurally tested. However, where a number of similar tanks is involved, one typical tank is to be structurally tested and for the remaining tanks the Surveyor may, at his discretion, permit leak testing in lieu of structural testing.
(c) Interconnecting deep and double bottom tanks and "flume" type stabilisation tanks are to be structurally tested to the test head given in *Table 1.7.1 Testing requirements*.

7.3.10 Equivalent proposals for testing will be considered.

7.3.11 **Trial trip and operational tests**. The items listed in *Table 1.7.2 Trial trip and operational tests* are to be tested on completion of the installation or at sea trials.

Table 1.7.2 Trial trip and operational tests

Item	Requirement
Sliding watertight doors	To be operated under working conditions.
Windlass	An anchoring test is to be carried out in the presence of the Surveyor. The test is to demonstrate that the windlass with brakes etc. functions satisfactorily and that the power to raise the anchor can be developed and satisfies the Rule requirements. For Rule requirements, *see Pt 3, Ch 5, 8 Anchor windlass design and testing*.
Steering gear, main and auxiliary	To be tested under working conditions, to the satisfaction of the Surveyors, to demonstrate that the Rule requirements are met. For Rule requirements, *see Pt 14, Ch 1 Steering Systems*.
Davits and deck cranes	To be tested under working conditions to proof load to the satisfaction of the Surveyors.
Fire flaps	To be operated under working conditions to the satisfaction of the Surveyors.
Means of escape	Alternative means of escape from machinery and accommodation spaces is to be proven to the satisfaction of the Surveyors. For Rule requirements, *see Pt 3, Ch 2, 4.10 Means of escape*.

■ *Section 8*
Building tolerances and associated repairs

8.1 Tolerances - General

8.1.1 Tolerances to be used regarding the acceptability of defects affecting raw materials are to be in accordance with *Pt 3, Ch 1, 8.2 Raw material surface tolerances*.

8.1.2 Tolerances to be used for constructional misalignment for all materials are to be discussed between Owners/Builders and the Surveyor and acceptable Standards agreed subject to the requirements of this Chapter or National Authority requirements where applicable. The permitted degree of inaccuracy/misalignment will vary according to whether the defect is:

(a) In primary structure.
(b) In secondary structure.
(c) Aesthetically pleasing.

8.1.3 The requirements in respect of constructional mis-alignment of steel/aluminium craft are to be found in *Pt 3, Ch 1, 8.6 Structural misalignment and fit (steel and aluminium)*. The requirements for construction using composite materials are contained in *Pt 8, Ch 2 Construction Procedures*.

8.2 Raw material surface tolerances

8.2.1 The surface cleanliness of steel/aluminium alloy materials in preparation for painting is to be in accordance with National or paint Manufacturer's Standards.

8.2.2 Where approved corrosion control coatings are to be used the quality of the surface treatment is to be in accordance with the grade specified in the approval documents.

8.3 Surface defects

8.3.1 The limits of depth and extent of surface defects on plate, cast or forged materials in relation to the material plate thickness are shown in *Table 1.8.1 Limits of surface defects*.

8.3.2 Defects are to be made good by grinding only subject to the plate thickness not being reduced by more than seven per cent of the nominal thickness or 3 mm whichever is the lower, and the area involved not exceeding two per cent of the surface area.

8.3.3 When the limits in *Pt 3, Ch 1, 8.3 Surface defects 8.3.1* are exceeded, plates may be made good by weld repair in accordance with the requirements specified in *Ch 13 Requirements for Welded Construction* of the *Rules for Manufacturing, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials.

8.3.4 Where the depth of the deepest imperfection exceeds 20 per cent of the nominal thickness, or the defective area exceeds two per cent of the total surface area, such areas are to be cropped and replaced. *See Pt 3, Ch 1, 8.5 Part replacement of plates*.

8.3.5 Complete removal of the defects is to be verified by suitable non-destructive examination techniques and after welding the repair is to be proved free from further defects. The complete removal of defects is to be verified by nondestructive examination in accordance with the requirements specified in *Ch 13 Requirements for Welded Construction* of the Rules for Materials.

8.3.6 Care is to be taken in the repair of defects in higher tensile steel, and aluminium alloy materials. Low hydrogen electrodes with similar properties to the higher tensile steel are to be used with preheating as necessary. Aluminium alloys are to be heat treated after repair, *see Pt 7, Ch 2, 3 Procedures for welded construction*.

Table 1.8.1 Limits of surface defects

Normal thickness of material (mm)	Maximum permissible depth of defect (mm)	
	Area affected - Unlimited	Area affected ≤ 5% of Surface
< 8	0,2	0,4
8 to 25	0,3	0,5
25 to 40	0,4	0,6

≥ 40	0,5	0,8
Note 1. Defects are to be measured after shot blasting or plate cleaning.		
Note 2. The depth of the deepest imperfection is to be considered.		
Note 3. Defects not exceeding the limits shown need not be repaired.		
Note 4. Where the depth of the defects reduces the material thickness to below the rolling/forging/casting tolerance (stated in the *Rules for the Manufacture, Testing and Certification of Materials, July 2021*) the values of column 2 and 3 will be accepted provided the areas involved do not exceed 15% and 2% respectively, of the plate/forging/casting surface.		
Note 5. Defects exceeding the above limits are to be repaired.		
Note 6. Crack-like defects are always to be repaired irrespective of their depth.		

8.4 Plate laminations

8.4.1 Plates in which laminations are suspected or detected are to be ultrasonically tested to determine the full extent of such laminations.

8.4.2 Where laminations are confined to the plate edge, are less than 300 mm long and whose penetration is not more than half the plate thickness, then the defect may be chipped or ground out and rebuilt with weld material.

8.4.3 Where laminations are isolated, located near to the plate surface, and where the total area of the defect does not exceed two per cent of the surface area of the plate, the defect may be repaired as in *Pt 3, Ch 1, 8.4 Plate laminations 8.4.2*.

8.4.4 Defective plate, with defects in excess of those stated in *Pt 3, Ch 1, 8.4 Plate laminations 8.4.2* and *Pt 3, Ch 1, 8.4 Plate laminations 8.4.3*, is to be cropped back and replaced, *see Pt 3, Ch 1, 8.5 Part replacement of plates*.

8.4.5 Complete removal of the defect is to be verified by non-destructive examination, and after welding, the repair is to be proved free from further defects.

8.5 Part replacement of plates

8.5.1 When defects exceed the limits laid down in *Pt 3, Ch 1, 8.3 Surface defects 8.3.4* and *Pt 3, Ch 1, 8.4 Plate laminations 8.4.4* above, the portion of the plate affected is to be cropped and replaced, *see Table 1.8.2 Part replacement of plates*.

8.6 Structural misalignment and fit (steel and aluminium)

8.6.1 For the requirements for the alignment and structural continuity of joints, *see Pt 6, Ch 2 Construction Procedures* and *Pt 7, Ch 2 Construction Procedures*.

8.6.2 *Table 1.8.3 Structural misalignment and fit (steel and aluminium)*, *Table 1.8.4 Structural misalignment and fit (steel and aluminium)* and *Table 1.8.5 Structural misalignment and fit (steel and aluminium)* define the minimum limits of accuracy required to be achieved in the various welded joint designs. When these values are not achieved, the defects are to be discussed and agreed by the Builder and the Surveyor before remedial action is taken.

8.6.3 Welding defects are generally to be dealt with in accordance with *Ch 13 Requirements for Welded Construction* of the Rules for Materials. Limits for weld undercut and remedial action to be taken depend on plate thickness and are to be discussed and agreed by the Builder and the Surveyor prior to commencement of repairs.

8.7 Post welding plate deformation

8.7.1 Post welding plate deformation for steel and aluminium alloy construction is to be limited, *see Table 1.8.6 Plate deformation limits* and *Figure 1.8.1 Measurement of plate deformation*.

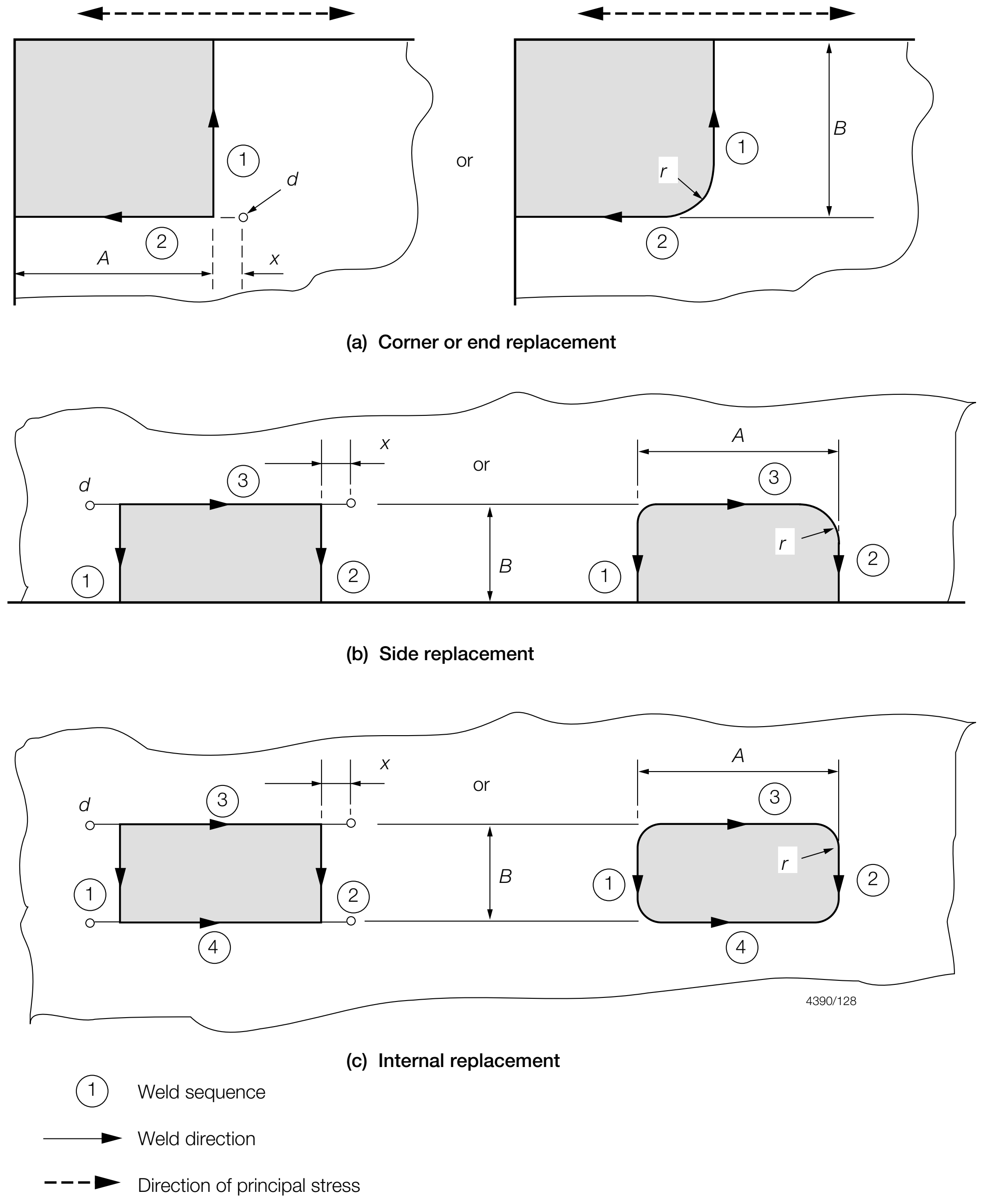
8.7.2 Deformation outside the limits of *Figure 1.8.1 Measurement of plate deformation* is to be faired by local heating or the plating renewed.

8.7.3 Local heating of steel is not to exceed 900ºC (red heat) when flame straightening is employed.

8.7.4 Local heating of aluminium alloys is not to be carried out. All repairs are to be by renewal of plating.

Table 1.8.2 Part replacement of plates

	Parts to be replaced	Shell, strength deck, tank top, top and bottom strakes of longitudinal bulkheads	Elsewhere
A x B	End and corner of plate	1000 x 1000	1000 x 300
	Side of plate	1000 x 300	1000 x 300
	Insert	1000 x 300	1000 x 300
Line of plate replacement to be not less than 100 from extreme edge of defect. All dimensions are in mm.			



Note 1. All dimensions are minimum.

Note 2. Rolling direction of replaced plate to be the same as that of the parent plate.

Note 3. Minimum distance from outermost defect to line of weld – 100 mm.

Note 4. Dimensions in millimetres:

x = 50

d = 1,5 x plate thickness with minimum 6 and maximum 20

r = 75 minimum

Table 1.8.3 Structural misalignment and fit (steel and aluminium)

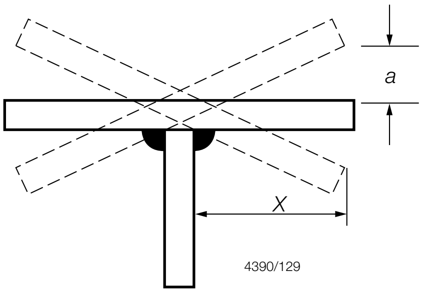
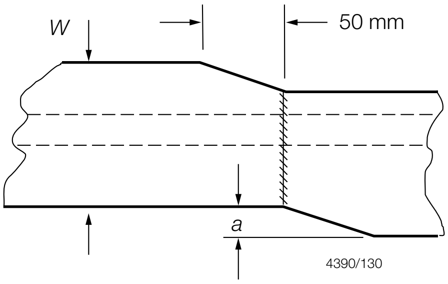
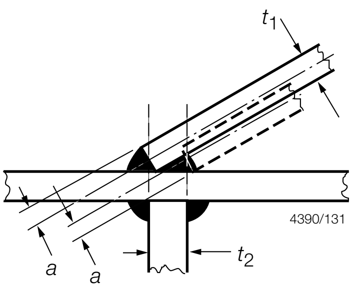
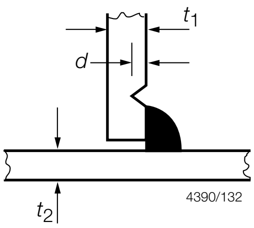
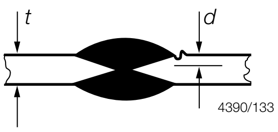
Joint	Location	Acceptable dimensions (mm)	Remedial action	
	Fabricated frames Beams, girders and longitudinals	$a \leq \pm$ 0,03 x	$a > \pm$ 0,03 x	Reject
	Butt welded face flats primary structure	$a \leq 0{,}03W$(max 6 mm)	$a > 0{,}03W$	Reject
	Secondary structure	$a \leq 0{,}04W$ (max 8 mm)	$a > 0{,}04W$	Reject
	Obtuse angle fillet weld	$a \leq t_1/2$	$a > t_1/2$	Reject
	All areas	$d \leq 0{,}1t_1$ (max 0,8 mm)	$d > 0{,}1t_1$	Repair by welding or grinding depends on thickness 't_1' in accordance with 8.3
	All areas	$d \leq 0{,}1t$ (max 0,8 mm)	$d > 0{,}1t$	As above

Table 1.8.4 Structural misalignment and fit (steel and aluminium)

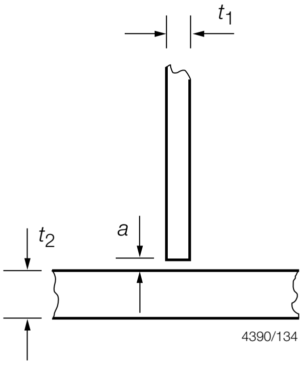
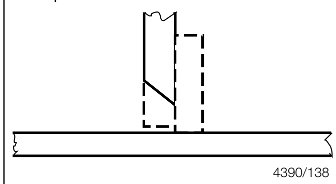
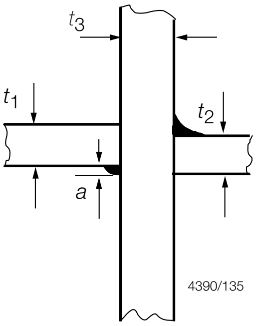
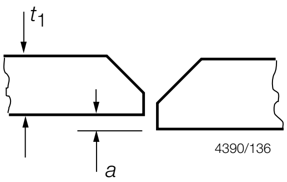
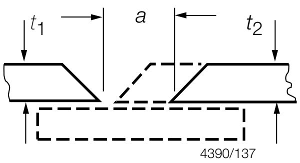
Joint	Location	Permitted misalignment	Remedial action	
	All areas (Continuous fillet weld)	a (mm) < 0,25t_1 (a max = 1 mm)	a (mm) 0,25t_1 to 0,5t_1 (t_1 max = 5 mm)	Increase weld leg length by 'a'
			0,5t_1 to t_1 (t_1 max = 15 mm)	Vee material to +/–45°. Fit backing strip and weld. Remove backing strip and complete weld. 
			$a > t_1$	Realign and replace
	All areas (intermittent weld)	< 0,25t_1	0,25 to 0,5t_1 (t_1 max = 3 mm)	Increase weld lengths by 50%
			0,25t_1 to 0,5t_1 (t_1 max = 5 mm)	Continuous weld
			$a > t_1$	As for continuous weld above
	Strength members	$a \leq t_2/3$	$t_2/3 \leq a \leq t_1/2$	Increase weld leg length of welds by 10%
	Others	$a \leq t_2/2$	$a > t_2/2$	Realign
	Higher tensile steel joint in designated critical areas	$a \leq t_3/3$	$a > t_3/3$	Realign
	Strength members	$a \leq 0,15t_1$(max 3,0 mm)	$a > 0,15t_1$	Realign
	Others	$a \leq 0,2t_1$ (max 3,0 mm)	$a > 0,2t_1$	Realign
	All areas	a in accordance with weld procedure	$a \leq t_1$	Build one side of butt until a in accordance with weld procedure.
			$a > t_1$ (max 10 mm)	Cut back 150 mm and fit insert plate

Table 1.8.5 Structural misalignment and fit (steel and aluminium)

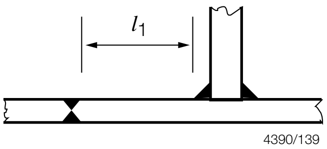
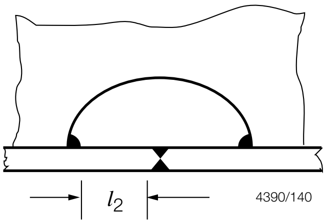
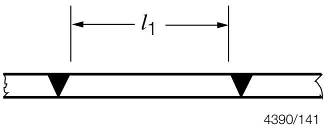
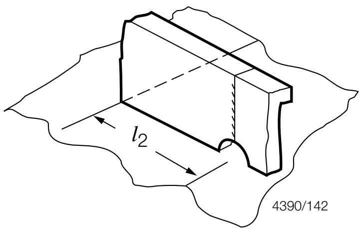
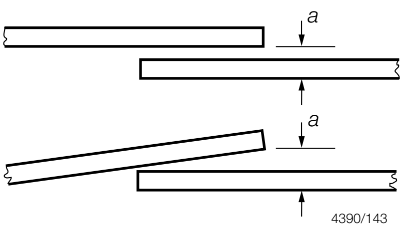
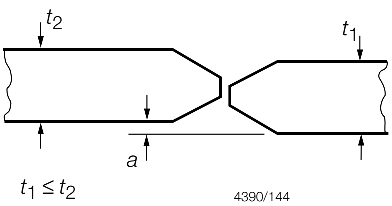
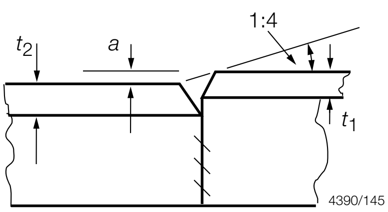
Joint	Location	Acceptable dimensions (mm)	Remedial action	
	All	$l_1 \geq 40$ mm	–	Adjust to suit
	All	$l_2 \geq 20$ mm	–	Adjust to suit
	All	$l_1 > 50$ mm	$l_1 < 30$ mm	Treat as an insert
	All	$l_2 \geq 20$ mm	$l_2 < 15$ mm	Adjust to suit
	All All	$a \leq 1{,}0$ $a \leq 1{,}0$	$a < 5$ $a \leq 5$	Increase weld leg length by actual '*a*' Adjust to suit
	Strength members Other	$a \leq 0{,}15t_1$ (max 3,0 mm) $a \leq 0{,}2t_1$ (max 3,0 mm)	$a > 0{,}15t_1$ $a > 0{,}2t_1$	Reject Reject
	All	For angle or tee longitudinal $a \leq 0{,}2t_1$ For offset bulb longitudinal $a \leq 0{,}2t_2$	$a > 0{,}2t_1$ $a > 0{,}2t_2$	Reject Reject

Table 1.8.6 Plate deformation limits

Position	s/t	δ_p/s
in 0,6L amidship	≤ 80	1/100
	> 80	1/75
Remainder	all	1/50

where

s = stiffener spacing, in mm

t = plating thickness, in mm

δ_p = panel deflection, in mm

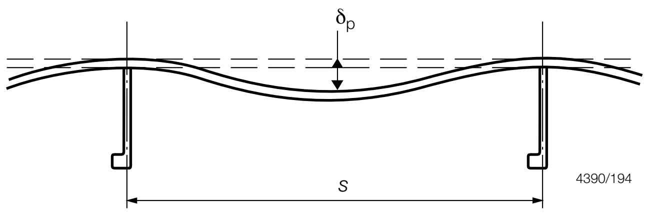


Figure 1.8.1 Measurement of plate deformation

Section

■ *Section 1* General

1.1 Application

1.1.1 This Chapter illustrates the general principles to be adopted in applying the structural requirements given in *Pt 4 Additional Requirements for Yachts*, *Pt 6 Hull Construction in Steel*, *Pt 7 Hull Construction in Aluminium* and *Pt 8 Hull Construction in Composite*. In particular, consideration has been given to the layout of the Rules as regards the different regions of the craft, principles for taper of hull scantlings, definition of span point, derivation of section moduli and basic design loading for deck structures. Principles for subdivision are also covered.

1.1.2 Where additional requirements relating to particular craft types apply, these requirements are indicated in the appropriate Parts and are to be complied with as necessary.

■ *Section 2* Rule structural concept

2.1 General

2.1.1 The Rules are based on the concept that the structural and watertight integrity and general safe operation of the craft will not be compromised by static and dynamic loads experienced during normal operating conditions.

2.2 Scantlings

2.2.1 Scantlings are generally based on the strength required to withstand loads imposed by the sea, cargo, passengers, ballast, bunkers and other operational loads. However, the Rules assume that the nature and stowage of the cargo, ballast, etc. are such as to avoid excessive structural stress.

2.2.2 Design loads and pressures as given in *Pt 5 Design and Load Criteria*, are to be used with scantling formulae or direct calculation methods to derive scantlings based on maximum allowable stress or other suitable strength criteria.

2.2.3 Hull structural vibration resulting from cyclic loadings arising from the sea and other sources are to be such that the normal operation and structural integrity of the craft are not impaired. However, these aspects are outwith the scope of classification, *see Pt 1, Ch 2, 1.4 Scope of classification*.

2.3 Definition of requirements

2.3.1 Static loads are based on standard conditions defined in *Pt 5 Design and Load Criteria*, or determined from loading conditions submitted by the Builder.

2.3.2 Dynamic loadings are examined for both the local and global structures. These loadings are based upon the designer's stated operational and environmental conditions or the Rule minimum criteria, whichever is the greater.

2.3.3 Wave induced loads are considered both in the static condition, i.e. hydrostatic and pitching pressures, and in the dynamic mode i.e. impact, slamming and hogging and sagging wave landing conditions.

2.3.4 Hull girder strength will in general require to be investigated dependent upon the length, configuration, proportions, proposed loadings etc. of the craft.

2.3.5 Scantling requirements in respect of miscellaneous items of structure such as local foundations, base plates, insert plates, etc. are not specifically indicated within these Rules. However the acceptance of such items will be specially considered on the basis of experience, good practice and direct calculation where appropriate.

2.4 Definitions and structural terms

2.4.1 The various definitions and structural terms for use throughout this Chapter are as indicated within the appropriate Section.

2.5 Symbols

2.5.1 The various symbols for use throughout this Chapter are as indicated within the appropriate Section.

■ *Section 3*
Structural idealisation

3.1 General

3.1.1 The scantling formulae in the Rules are normally based on elastic or plastic theory using simple beam models supported at one or more points and with varying degrees of fixity at the ends, in association with an appropriate concentrated or distributed load for steel and aluminium craft.

3.1.2 Apart from a local requirement for web or flange thicknesses, the stiffener, beam or girder strength is defined by a section modulus and moment of inertia requirement.

3.1.3 For the derivation of scantlings for fibre composite structures, the formulae are based on equivalent load carrying capability, with limitations on both allowable stress and strain, in addition to deflection controls.

3.2 Geometric properties of sections

3.2.1 The symbols used in this sub-Section are defined as follows:

b = the actual width, in metres, of the load-bearing plating, i.e. one-half of the sum of spacings between parallel adjacent members or equivalent supports

f = $0,3\left(\frac{l}{b}\right)^{\frac{2}{3}}$

= but is not to exceed 1,0. Values of this factor are given in *Table 2.3.1 Values of factor f*

l = the overall length, in metres, of the primary support member, as indicated in *Figure 3.1.2 Span points* and *Figure 3.1.2 Span points*, respectively, for steel and aluminium alloy construction and *Figure 3.1.3 Span points* for composite construction

t_p = the thickness, in mm, of the attached plating. Where this varies, the mean thickness over the appropriate span is to be used.

Table 2.3.1 Values of factor *f*

$\frac{l}{b}$	f	$\frac{l}{b}$	f
0,5	0,19	3,5	0,69
1,0	0,30	4,0	0,76
1,5	0,39	4,5	0,82
2,0	0,48	5,0	0,88
2,5	0,55	5,5	0,94
3,0	0,62	6,0 and above	1,00
NOTE Intermediate values to be obtained by linear interpolation.			

3.2.2 The effective geometric properties of rolled or built sections may be calculated directly from the dimensions of the section and associated effective area of attached plating. Where the web of the section is not normal to the attached plating, and the angle exceeds 20°, the properties of the section are to be determined about an axis parallel to the attached plating.

3.2.3 The geometric properties of rolled or built stiffener sections and of swedges are to be calculated in association with effective area of attached load bearing plating of thickness $t_p$mm and of width as given by *Pt 6, Ch 3, 1.10 Effective width of attached plating* or *Pt 7, Ch 3, 1.11 Effective width of attached plating* for steel and aluminium alloy construction respectively. In no case, however, is the width of plating to be taken as greater than either the spacing of the stiffeners or the width of the flat plating between swedges, whichever is appropriate. The thickness, t_p, is the actual thickness of the attached plating. Where this varies, the mean thickness over the appropriate span is to be used.

3.2.4 The effective section modulus of a corrugation over a spacing, s_c, is to be calculated from the dimensions and, for symmetrical corrugations, may be taken as:

$$z = \frac{d_w\left(3bt_p + ct_w\right)}{6000} \text{cm}^3$$

where d_w, b, t_p, c and t_w are measured, in mm, and are as shown in *Figure 2.3.1 Corrugation*. The value of b is to be taken not greater than:

$50t_p\sqrt{\frac{235}{\sigma_o}}$ for welded corrugations

$60t_p\sqrt{\frac{235}{\sigma_0}}$ for cold formed corrugations

where σ_0 is defined in *Pt 3, Ch 3, 1.2 General*.

The value of θ is not to be taken less than 40°. The moment of inertia is to be calculated from:

$$I = 0,05\, d_w Z \text{ cm}^4$$

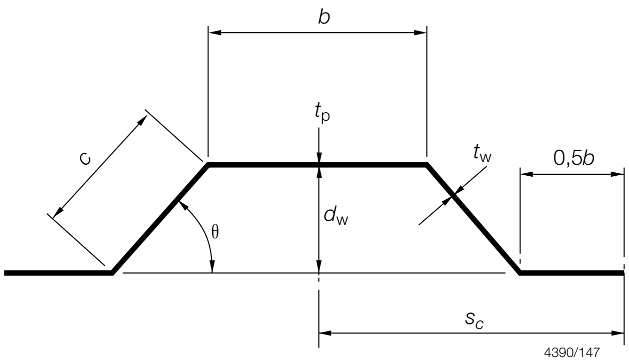


Figure 2.3.1 Corrugation

3.2.5 The section modulus of a double plate bulkhead over a spacing *b* may be calculated as:

$$Z = \frac{d_w \left(6 f\, b\, t_p + d_w t_w\right)}{6000} \text{ cm}^3$$

where d_w, b, t_p and t_w are measured, in mm, and are as shown in *Figure 2.3.2 Double plate bulkhead*.

3.2.6 The effective stiffness and the effective stress response of profiles of which the web has openings with a height more than 50 per cent of the web depth, or where the width of intact plate between openings is less than the maximum size of the openings, are to be determined by direct calculation based on the actual arrangement of the openings.

3.2.7 The effective section modulus of a fabricated section may be taken as:

$$Z = \frac{a\, d_w}{10} + \frac{t_w d_w^{\,2}}{6000}\left(1 + \frac{200(A - a)}{200A + t_w d_w}\right) \text{cm}^3$$

where

a = the area of the face plate of the member, in cm^2

d_w = the depth, in mm, of the web between the inside of the face plate and the attached plating. Where the member is at right angles to a line of corrugations, the minimum depth is to be taken

t_w = the thickness of the web of the section, in mm

A = the area, in cm^2, of the attached plating, *see Pt 3, Ch 2, 3.2 Geometric properties of sections 3.2.8*. If the calculated value of A is less than the face area a, then A is to be taken as equal to a

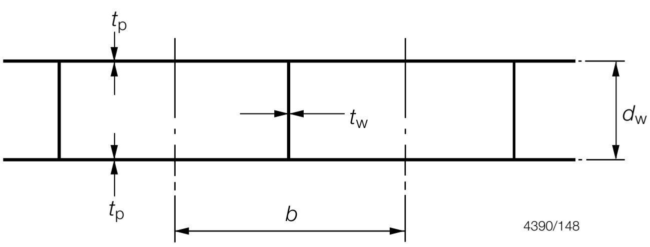


Figure 2.3.2 Double plate bulkhead

3.2.8 The geometric properties of primary support members (i.e. girders, transverses, webs, stringers, etc.) are to be calculated in association with an effective area of attached load bearing plating, A, determined as follows:

(a) For a member attached to plane plating:

$$A = 10 f_b t_p \text{ cm}^2$$

where f is as defined in *Pt 3, Ch 2, 3.2 Geometric properties of sections 3.2.1*.

(b) For a member attached to corrugated plating and parallel to the corrugations:

$$A = 10 b t_p \text{ cm}^2$$

(*See Figure 2.3.1 Corrugation*)

(c) For a member attached to corrugated plating and at right angles to the corrugations:

- *A* is to be taken as equivalent to the area of the face plate of the member.

3.3 Determination of span point

3.3.1 The effective span, l_e, of a stiffening member is to be as defined in *Pt 6 Hull Construction in Steel*, *Pt 7 Hull Construction in Aluminium* and *Pt 8 Hull Construction in Composite*, for steel, aluminium alloy and composite construction respectively.

3.4 Calculation of hull section properties

3.4.1 The particular requirements for the calculation of the hull section modulus for craft of steel and aluminium alloy construction are defined in *Pt 6, Ch 6 Hull Girder Strength* and *Pt 7, Ch 6 Hull Girder Strength* respectively. The particular requirements for the hull section stiffness for craft of composite construction are defined in *Pt 8, Ch 6 Hull Girder Strength*.

■ *Section 4*
Bulkhead arrangements

4.1 General

4.1.1 The criteria on bulkhead arrangements in this Section apply to seagoing craft. Bulkhead arrangements for non-seagoing craft will be specially considered based on the structural requirements and the requirements of the authority where the craft is registered. In the absence of National Authority requirements the relevant requirements of the *Rules and Regulations for the Classification of Inland Waterways Ships, July 2021* are to be complied with.

4.1.2 Watertight bulkheads are, in general, to extend to the uppermost continuous watertight deck, hereinafter referred to as the bulkhead deck, and their construction is to be in accordance with *Pt 6 Hull Construction in Steel*, *Pt 7 Hull Construction in Aluminium* and *Pt 8 Hull Construction in Composite* as appropriate.

4.1.3 Where openings are permitted in bulkheads they are to be provided with suitable closing devices in accordance with *Pt 3, Ch 4, 2 Bulkhead openings*.

4.2 Number and disposition of bulkheads

4.2.1 All craft with a Rule length, L_R, greater than 15 m are to have a collision bulkhead.

4.2.2 In motor craft with a Rule length, L_R, less than or equal to 15 m, the machinery is to be enclosed by gastight bulkheads to protect accommodation spaces from gas and vapour fumes from machinery, exhaust and fuel systems.

4.2.3 Where the aft peak bulkhead does not enclose the hull penetration for the sterntube, *see Pt 3, Ch 3, 3.13 Sterntubes 3.13.14*.

4.2.4 All craft with a Rule length, L_R, greater than 15 m are to have a watertight bulkhead at each end of the machinery space, where the machinery is amidships or a watertight bulkhead at the forward end of the machinery space, where the machinery is aft.

4.2.5 All craft with a Rule length, L_R, greater than 25 m are to have a watertight bulkhead at each end of the machinery space, with the aft peak bulkhead forming the aft bulkhead of the machinery space, where the machinery is aft.

4.2.6 Additional watertight bulkheads are to be fitted so that the total number of bulkheads is at least in accordance with *Table 2.4.1 Total number of bulkheads*.

Table 2.4.1 Total number of bulkheads

Length, L_R, in metres		Total number of bulkheads	
		Machinery amidships	Machinery aft
> 15	≤ 25	3	2
> 25	≤ 65	4	3*
> 65	≤ 85	4	4*
> 85	≤ 90	5	5*
> 90	≤ 105	5	5*
> 105	≤ 115	6	5*
> 115	≤ 125	6	6*
> 125	≤ 145	7	6*
> 145		To be individually considered	
* With afterpeak bulkhead forming after boundary of machinery space			

4.2.7 Bulkheads are to be spaced at reasonably uniform intervals. Where non-uniform spacing is unavoidable and the length of a compartment is unusually great, the transverse strength of the craft is to be maintained by fitting of web frames, increased framing, etc. and details are to be submitted.

4.2.8 Proposals to dispense with one or more of these bulkheads will be considered, subject to suitable structural compensation, if they interfere with the requirements of a special trade.

4.2.9 Where applicable, the number and disposition of bulkheads are to be arranged to suit the requirements for subdivision, floodability and damage stability, and are to be in accordance with the requirements of the National Authority.

4.3 Collision bulkhead

4.3.1 The collision bulkhead in all craft other than passenger craft, patrol craft and yachts is to be positioned as detailed in *Table 2.4.2 Collision bulkhead position (excluding passenger craft, patrol craft and yachts)*. Consideration will, however, be given to proposals for the collision bulkhead to be positioned slightly further aft on Arrangement (b) craft, but not more than $0{,}08L_L$ from the fore end of L_L, provided that the application is accompanied by calculations showing that flooding of the space forward of the collision bulkhead will not result in any part of the freeboard deck becoming submerged, or any unacceptable loss of stability. Special consideration may be given to the extent of the collision bulkhead above the bulkhead deck for multi-hull craft.

Table 2.4.2 Collision bulkhead position (excluding passenger craft, patrol craft and yachts)

Arrangement	Length, L_L	Distance of collision bulkhead aft of the fore end of L_L, in metres	
		Minimum	Maximum
(a)	≤ 150	$0{,}05L_L$	$0{,}08L_L$
(b)	≤ 150	$0{,}05L_L - f_1$	$0{,}08L_L - f_1$
Symbols and definitions			

$f_1 = \dfrac{G}{2}$ or $0{,}015L_L$, whichever is the lesser

G = Projection of bulbous bow forward of fore end of L_L, in metres

L_L is as defined in *Pt 3, Ch 1, 6.2 Principal particulars*

Arrangement (a) A craft that has no part of its underwater body extending forward of the fore end of L_L.

Arrangement (b) A craft with part of its underwater body extended forward of the fore end of L_L (e.g. bulbous bow).

4.3.2 The collision bulkhead in passenger craft, patrol craft and yachts is to be in accordance with the following:

(a) A craft shall have a forepeak or collision bulkhead, which shall be watertight up to the bulkhead deck. (The bulkhead deck is the uppermost deck up to which the transverse watertight bulkheads are carried, *see Pt 3, Ch 2, 4.2 Number and disposition of bulkheads 4.2.9*). This bulkhead is to be positioned as detailed in *Table 2.4.3 Collision bulkhead for passenger craft, patrol craft and yachts*.

(b) If the craft has a long forward superstructure, the forepeak or collision bulkhead is to be extended weathertight to the deck next above the bulkhead deck. The extension need not be fitted directly over the bulkhead below, provided it is located within the limits specified in *Table 2.4.3 Collision bulkhead for passenger craft, patrol craft and yachts* with the exemption permitted by *Pt 3, Ch 2, 4.6 Watertight recesses, flats and loading ramps 4.6.3* and the part of the bulkhead deck which forms the step is made effectively weathertight.

Table 2.4.3 Collision bulkhead for passenger craft, patrol craft and yachts

Arrangement	Distance of collision bulkhead aft of fore perpendicular, in metres	
	Minimum	Maximum
(a)	$0{,}05L_{pp}$	$3 + 0{,}05L_{pp}$
(b)	$0{,}05L_{pp} - f$	$3 + 0{,}05L_{pp} - f$
Symbols and definitions		
$f = \dfrac{G}{2}$ or $0{,}015L_{pp}$, whichever is the lesser G = Projection of bulbous bow forward of fore perpendicular, in metres L_{pp} is as defined in *Pt 3, Ch 1, 6.2 Principal particulars* . Arrangement (a) A craft that has no part of its underwater body extending forward of the fore perpendicular. Arrangement (b) A craft with part of its underwater body extending forward of the fore perpendicular (e.g. bulbous bow).		

4.3.3 Alternative arrangements may be submitted for consideration in the case of sailing and auxiliary craft.

4.3.4 For craft with pronounced rake of stem, the position of the collision bulkhead will be specially considered.

4.3.5 Accesses are not to be fitted in collision bulkheads. In particular designs where it would be impracticable to arrange access to the fore peak other than through the collision bulkhead, access may be permitted subject to special consideration. Where accesses are provided, the openings are to be as small as practicable and positioned as far above the design waterline as possible. The closing appliances are to be watertight, to open into the fore peak compartment and consideration will be given to operation from one side only.

4.4 Aft peak bulkhead

4.4.1 An aft peak bulkhead, where required to be fitted (in each half of a multi-hull craft) is, in general, to enclose the sterntube, water jet unit, etc. in a watertight compartment. Where the aft peak bulkhead does not enclose the hull penetration for the sterntube, waterjet unit, etc. *see Pt 3, Ch 3, 3.13 Sterntubes 3.13.14*. *See also Table 2.4.1 Total number of bulkheads*.

4.5 Height of bulkhead

4.5.1 The collision bulkhead is to extend to the uppermost continuous deck or, in the case of craft with combined bridge and forecastle or a long superstructure which includes a forecastle, to the superstructure deck if the superstructure is considered effective in stability. However, if a craft is fitted with more than one complete superstructure deck, the collision bulkhead may be terminated at the deck next above the freeboard deck. Where the collision bulkhead extends above the freeboard deck, the extension need only be to weathertight standards.

4.5.2 The aft peak bulkhead may terminate at the first deck above the load waterline, provided that this deck is made watertight to the stern or to a watertight transom floor. In passenger craft the aft peak bulkhead is to extend watertight to the bulkhead deck. However, it may be stepped below the bulkhead deck provided the degree of safety of the craft as regards watertight subdivision is not thereby diminished.

4.5.3 The remaining watertight bulkheads are to extend to the bulkhead deck. In passenger craft of restricted draught and all craft of unusual design, the height of the bulkheads will be specially considered.

4.6 Watertight recesses, flats and loading ramps

4.6.1 Watertight recesses in bulkheads are generally to be so framed and stiffened as to provide strength and stiffness equivalent to the requirements for watertight bulkheads.

4.6.2 In collision bulkheads, any recesses or steps in the bulkhead are to fall within the limits of bulkhead positions given in *Pt 3, Ch 2, 4.3 Collision bulkhead 4.3.1* or *Pt 3, Ch 2, 4.3 Collision bulkhead 4.3.3* as applicable. Where the bulkhead is extended above the freeboard deck, or bulkhead deck in passenger craft, the extension need only be to weathertight standards. If a step occurs at that deck, the deck need also only be to weathertight standards in way of the step, unless the step forms the crown of a tank, in which case the requirements for deep tank structures are to be complied with.

4.6.3 In craft fitted with bow doors, in which a sloping loading ramp forms part of the collision bulkhead above the freeboard or bulkhead deck, that part of the ramp which is more than 2,30m above the freeboard or bulkhead deck may extend forward of the minimum limit specified in *Table 2.4.2 Collision bulkhead position (excluding passenger craft, patrol craft and yachts)* or *Table 2.4.3 Collision bulkhead for passenger craft, patrol craft and yachts* as appropriate. Such a ramp is to be weathertight over its complete length.

4.7 Gastight bulkheads

4.7.1 Where bulkheads are required to be gastight in accordance with *Pt 3, Ch 2, 4.2 Number and disposition of bulkheads 4.2.2*, and where it is proposed to pierce such bulkheads for the passage of cables, pipes, vent trunking etc. gastight glands are to be provided to maintain the gastight integrity.

4.8 Tank bulkheads

4.8.1 The scantlings of deep tank bulkheads are to be in accordance with *Pt 6, Ch 3, 7 Bulkheads and deep tanks*, *Pt 7, Ch 3, 7 Bulkheads and deep tanks* and *Pt 8, Ch 3, 7 Bulkheads and deep tanks*, for steel, aluminium alloy and composite structures respectively.

4.8.2 Air and sounding pipes are to comply with the requirements of *Pt 15, Ch 2, 11 Air, overflow and sounding pipes*.

4.9 Separation and protection of tanks

4.9.1 Where the cross contamination of liquid consumables stored in adjacent tanks could be hazardous to machinery, these tanks are to be separated by cofferdams. Hazardous pairings of liquid consumables include but are not limited to the following:

(a) Fuel oil and lubricating oil.
(b) Fuel oil and technical water (e.g. feedwater).
(c) Lubricating oil and technical water.

4.9.2 Tanks carrying liquids for the purposes of fire-fighting (e.g. foam concentrate) are to be separated by cofferdams from adjacent tanks containing liquid fuels.

4.9.3 Tanks carrying fresh water for human consumption (potable water) are to be separated by cofferdams from adjacent tanks containing liquid substances harmful to human health. Fresh water for other purposes and water ballast are not considered harmful.

4.9.4 Where a cofferdam as specified in *Pt 3, Ch 2, 4.9 Separation and protection of tanks 4.9.1* is impracticable, special consideration may be given, subject to the arrangements complying with the following:

(a) In metal construction the common boundary plates shall have full penetration welds.
(b) In composite construction, an adequate barrier of lining or coating of resistant material is required between the fluid and the laminate. The resin for the composite construction is to be compatible with the content of the tank. The core material for sandwich construction is to be end grain balsa or closed cell PVC foam. With balsa core, gaps between each block are to be filled with resin. If any part of a stiffener runs through the tank, then that part of the stiffener core is to be isolated using resin filled buffers, or equivalent, outside of the tank boundaries. Details are to be submitted for appraisal.

4.9.5 Where a corner to corner situation occurs, tanks are not considered to be adjacent, but any welds near the corner joining the continuous plate are to be full penetration welds.

4.9.6 Where fitted, cofferdams are to be suitably ventilated, provided with a suitable drainage arrangement, and be of sufficient size to allow proper inspection, maintenance and safe evacuation.

4.9.7 If fuel oil tanks are necessarily located within or adjacent to the machinery spaces, their arrangement is to be such as to avoid direct exposure of the bottom from rising heat resulting from a machinery or hazardous space fire. In addition SOLAS Regulation II-2/B4.2.2.3.2, where applicable, shall be adhered to. Alternative standards consistent with SOLAS Regulation II-2/B4.2.2.3.2 can be applied.

4.9.8 Attention is drawn to the Flag Administration requirement's concerning separation and protection of tanks.

4.10 Means of escape

4.10.1 The arrangement of the hull is to be such that all underdeck compartments are as accessible as practicable and provided with a satisfactory means of escape. Access and escape hatches to the machinery and tanks are not to be obstructed by deck coverings or fixed furniture. Special consideration may be given to escape arrangements through raised deck areas or fixed furniture where the escape trunk is an integral part of the raised area or the fixed furniture. Access and escape hatches are not to have their operation obstructed.

4.11 Carriage of low flash point fuels

4.11.1 Special provision is to be made for the carriage of low flash point fuel in accordance with *Pt 15, Ch 3, 5 Low flash point fuels*.

■ *Section 5* Fore and aft end arrangements

5.1 General

5.1.1 The requirements in respect of the general constructional arrangements for mono-hull craft covered by the Rules are contained within this Section.

5.2 Structural configuration

5.2.1 The Rules provide for both longitudinal and transverse framing systems.

5.3 Structural continuity

5.3.1 Suitable scarfing arrangements are to be made to ensure continuity of strength and the avoidance of abrupt structural changes.

5.3.2 Where longitudinal framing terminates and is replaced by a transverse system, adequate arrangements are to be made to avoid an abrupt changeover. Where a forecastle is fitted extending aft of 0,15*L* from the F.P., longitudinal framing at the upper deck and topsides is generally to be continued forward of the end bulkhead of this superstructure.

5.4 Minimum bow height and reserve buoyancy

5.4.1 All sea-going craft are to be fitted with forecastles, or increased sheer on the upper deck or equivalent, such that the distance from the summer load waterline to the top of the exposed deck at side at the F.P. is not less than:

$$H_b = \left(6075\left(\frac{L_L}{100}\right) - 1875\left(\frac{L_L}{100}\right)^2 + 200\left(\frac{L_L}{100}\right)^3\right)$$

$$x\left(2,08 + 0,609C_b - 1,603C_{wf} - 0,0129\left(\frac{L_L}{d_1}\right)\right)$$

where

d_1 = draught at 85 per cent of the depth D, in metres

A_{wf} = waterplane area forward of $\frac{L_L}{2}$ at draught d_1, in m^2.

where

B = moulded breadth, in metres

C_b = block coefficient as defined in the Load Lines Convention

C_{wf} = the waterplane area coefficient forward of

$$C_{wf} = \frac{A_{wf}}{\left(\frac{L_L}{2}\right) x B}$$

H_b = minimum bow height

L_L = Load Line length, in metres

5.4.2 Craft which are designed to suit exceptional operational requirements, restricted in their service to Group G1, or of novel configuration will be specially considered on the basis of the Rules.

5.4.3 Where the bow height required in *Pt 3, Ch 2, 5.4 Minimum bow height and reserve buoyancy 5.4.1* is obtained by sheer, the sheer shall extend for at least 15 per cent of the length of the craft measured abaft the forward end of L_L. Where it is obtained by fitting a forecastle, the forecastle shall extend from the stem to a point at least 0,07L_L abaft the forward end of L_L, and shall be enclosed.

5.4.4 Craft shall have additional reserve buoyancy in the fore end in accordance with the Load Lines Convention.

5.5 Bow crumple zone

5.5.1 In general the bow crumple zone is that space forward of the collision bulkhead. Passenger and crew accommodation and the carriage of fuel and other oils are not permitted in the bow crumple zone.

5.6 Strengthening of bottom forward

5.6.1 Except for craft with **G2** service notations, additional strengthening of bottom forward may be required for seagoing craft with rule length, L_R, greater than 65 m. Details are to be submitted for consideration.

5.7 Bulbous bows

5.7.1 Where a bulbous bow is fitted, the structural arrangements are to be such that the bulb is adequately supported and integrated into the fore peak structure.

5.7.2 At the fore end of the bulb the structure is generally to be supported by horizontal diaphragm plates spaced generally 1,0 m apart in conjunction with a deep centreline web.

5.7.3 In general, vertical transverse diaphragm plates are to be arranged in way of the transition from the peak framing to the bulb framing.

5.7.4 In way of a wide bulb, additional strengthening in the form of a centreline wash bulkhead is generally to be fitted.

5.7.5 In way of a long bulb, additional strengthening in the form of transverse wash bulkheads or substantial web frames spaced about five frame spaces apart are generally to be fitted.

5.7.6 The shell plating is to be increased in thickness at the fore end of the bulb and in other areas likely to be damaged by the anchors and chain cables. The increased plate thickness is to be the same as that required for plated stems.

5.8 Strengthening against bow flare slamming

5.8.1 Where a craft has pronounced flare or rake of bow, the structure in the forward region will be subject to special consideration, and the scantlings and arrangements may require additional strengthening.

Section 6
Machinery space arrangements

6.1 General

6.1.1 This Section applies to all craft types. Only requirements particular to machinery spaces, including protected machinery casings and engine seatings, are given. For other scantlings and arrangement requirements, *see* the relevant Chapter in *Pt 6 Hull Construction in Steel*, *Pt 7 Hull Construction in Aluminium* and *Pt 8 Hull Construction in Composite*.

6.2 Structural configuration

6.2.1 Requirements are given for craft constructed using either a transverse or longitudinal framing system, or a combination of the two. For requirements for sandwich construction *see Pt 8, Ch 2 Construction Procedures* and *Pt 8, Ch 3 Scantling Determination for Mono-Hull Craft* for composite mono-hull craft and composite multi-hull craft respectively.

6.2.2 For machinery spaces situated aft, where the longitudinal framing terminates and is replaced by transverse framing, a suitable scarfing arrangement of the longitudinal framing is to be arranged. *See also Pt 3, Ch 2, 5.3 Structural continuity*.

6.2.3 The maximum spacing, S_{max}, of web frames in longitudinally framed machinery spaces is not to exceed 3,8 m. Additionally for transversely framed craft, in way of a machinery space situated adjacent to the aft peak, the spacing of web frames is not to exceed six transverse frame spaces.

6.3 Structural continuity

6.3.1 Suitable scarfing arrangements are to be made to ensure continuity of strength and the avoidance of abrupt discontinuities where structure which contributes to the main longitudinal strength of the craft is omitted in way of a machinery space.

6.4 Deck structure

6.4.1 The corners of machinery space openings are to be of suitable shape and design to minimise stress concentrations.

6.4.2 In motor craft having a Rule length L_R, less than 15 m, the machinery is to be enclosed by gastight decks to protect accommodation spaces from gas and vapour fumes from machinery, exhaust and fuel systems.

6.5 Side shell structure

6.5.1 Side shell structure is to be constructed in accordance with the scantlings indicated in *Pt 6 Hull Construction in Steel*, *Pt 7 Hull Construction in Aluminium* and *Pt 8 Hull Construction in Composite*, for steel, aluminium alloy and composite structures respectively.

6.5.2 General requirements for web frames are given in this Section for both longitudinal and transverse framing systems. Where longitudinal framing is adopted in the midship region it is to be carried as far forward and aft as practicable.

6.5.3 A transverse framing system is to be additionally reinforced by web frames fitted six frame spaces apart. Where a longitudinal framing system is adopted, the spacing of the transverses is not to exceed 2,5 m.

6.6 Double and single bottom structure

6.6.1 Flag state requirements for double and single bottom structures are to be complied with. In the absence of specific Flag state requirements for double and single bottom structures, arrangements in accordance with SOLAS will be acceptable.

6.6.2 Margin plates and drainage wells are to be provided as necessary and subject to special consideration.

6.6.3 The scantlings of bottom stiffening, floors, centre girders and side girders are to be in accordance with the appropriate Sections of *Pt 6 Hull Construction in Steel*, *Pt 7 Hull Construction in Aluminium* and *Pt 8 Hull Construction in Composite* of the Rules, for craft built in steel, aluminium alloy and composite respectively.

6.6.4 In motor craft the thickness of the floors in machinery spaces is to be 1mm greater than that required by the appropriate Sections of *Pt 6 Hull Construction in Steel*, *Pt 7 Hull Construction in Aluminium* and *Pt 8 Hull Construction in Composite* of the Rules, for craft built in steel and aluminium alloy respectively.

6.6.5 In craft having considerable rise of floor, the depth of the floor plate, or its height at side, may require to be increased. The transverse extent of double bottom will be specially considered.

6.6.6 Suitable arrangements are to be made to provide free passage of water from all parts of the bilge to the pump suctions.

6.6.7 A centreline girder is to be fitted in association with transverse frames, transverses supporting longitudinals or where the breadth of floors at the upper edge is greater than 1,5 m. Where the breadth of the floors at the upper edge exceeds 6,0 m a side girder is also to be fitted each side of the centre girder.

6.6.8 All girders are to extend as far forward and aft as practicable and care is to be taken to avoid any abrupt discontinuity.

6.6.9 Centreline girders fitted in association with flat plate keels are to be formed of intercostal or continuous plates with a continuous face flat welded on the upper edge.

6.6.10 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with *Pt 3, Ch 2, 6.8 Integral fuel tanks*.

6.7 Machinery casings

6.7.1 The scantlings and arrangements of exposed casings protecting machinery openings are to be in accordance with *Pt 6, Ch 3, 9.8 Machinery casing plating* and *Pt 7, Ch 3, 9.8 Machinery casing plating*, for craft built in steel and aluminium alloy respectively.

6.7.2 Where casing stiffeners carry loads from deck transverses, girders, etc. or where they are in line with pillars below, they are to be suitably increased. *See also Pt 6, Ch 3, 10 Pillars and pillar bulkheads Pt 7, Ch 3, 10 Pillars and pillar bulkheads* and *Pt 8, Ch 3, 10 Pillars and pillar bulkheads*, for craft built in steel, aluminium alloy and composite respectively.

6.7.3 Where casing sides act as girders supporting decks over, care is to be taken that access openings do not seriously weaken the structure. Openings are to be effectively framed and reinforced if found necessary. Particular care is to be paid to stiffening where the casing supports the funnel or exhaust uptakes.

6.7.4 Casing bulkheads are to be made gastight and the access doors are to be of a gastight self-closing type.

6.8 Integral fuel tanks

6.8.1 The scantlings of deep tank bulkheads are to be in accordance with *Pt 6, Ch 3, 7 Bulkheads and deep tanks*, *Pt 7, Ch 3, 7 Bulkheads and deep tanks* and *Pt 8, Ch 3, 7 Bulkheads and deep tanks*, for craft built in steel, aluminium alloy and composite respectively.

6.9 Machinery seatings

6.9.1 Main and auxiliary engines in motor and auxiliary sailing craft are to be effectively secured to the hull structure by seatings of adequate scantlings to resist the gravitational, thrust, torque and vibrating forces which may be imposed upon them.

6.9.2 The longitudinal girders forming the engine seatings are to extend as far forward and aft as practicable and be adequately supported by transverse floors or brackets.

6.9.3 In determining the scantlings of seats for oil engines, consideration is to be given to the design characteristics of the engine with regard to out of balance forces. For machinery room arrangements, *see Pt 5, Ch 1, 4 Machinery room arrangements*.

6.9.4 Scantlings for the seats of the drive train should consider the rigidity of its components and the design characteristics of individual components.

6.9.5 The seats are to be so designed that they distribute the forces from the engine(s) as uniformly as possible into the supporting structure. Longitudinal girders supporting the seatings are to be arranged in single or double bottoms, and are, in general, to extend over the full length of the machinery space. The ends of the girders are to be scarfed into the bottom structure for at least two frame spaces. Adequate transverse brackets are to be arranged in line with floors. Small brackets may be required under the top plate in way of holding down bolts.

6.9.6 For gas turbine installations, seats are to be so designed as to provide effective support and ensure their proper alignment with the gearing, and, where applicable, allow for thermal expansion of the casings. In general, the seats are not to be arranged in way of breaks or recesses in the double bottom.

6.9.7 Auxiliary machinery is to be secured on seatings, of adequate scantlings, so arranged as to distribute the loadings evenly into the supporting structure.

6.10 Thrust blocks

6.10.1 Main engines and thrust bearings are to be effectively secured to the hull structure by seatings of adequate scantlings to resist the various gravitational, thrust, torque, dynamic and vibratory forces which may be imposed on them.

6.10.2 For initial guidance, it is recommended that the scantlings for oil engine seatings be as indicated in *Pt 3, Ch 2, 6.9 Machinery seatings 6.9.3*.

■ *Section 7*
Superstructures, deckhouses and bulwarks

7.1 General

7.1.1 Superstructures, deckhouses and bulwarks are to be constructed in accordance with the scantlings indicated in *Pt 6, Ch 3, 9 Superstructures, deckhouses and bulwarks*, *Pt 7, Ch 3, 9 Superstructures, deckhouses and bulwarks* and *Pt 8, Ch 3, 9 Superstructures, deckhouses and bulwarks*, for steel, aluminium alloy and composite structures respectively.

7.2 Definition of tiers

7.2.1 The lowest, or first tier, is normally that which is directly situated on the deck to which *D* is measured. The second tier is the next tier above the lowest tier and so on. *See Figure 2.7.1 Definition of tiers*.

7.2.2 Where the vertical distance between the weather deck and the summer load waterline is equal to or greater than the sum of the minimum freeboard and one standard superstructure height, then proposals to treat the first tier erection as a second tier, and so on, will be specially considered. The standard height of superstructure is the height defined in *Pt 3, Ch 1, 6.13 Superstructure 6.13.3*. *See Figure 2.7.1 Definition of tiers*.

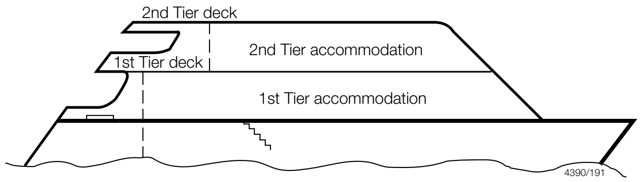


Figure 2.7.1 Definition of tiers

7.2.3 Suitable scarfing arrangements are to be made to ensure continuity of strength and the avoidance of abrupt structural changes.

7.3 Unusual designs

7.3.1 Craft or structural arrangements which are of unusual design, form or proportions will be individually considered. Special features will be considered in each separate case.

■ *Section 8*
Particular requirements for multi-hulls

8.1 General

8.1.1 The requirements indicated in this Section are particular to multi-hull craft and are to be applied in addition to the general requirements of this Chapter.

8.1.2 The craft is to be considered as one complete structure when determining the minimum geometric summer freeboard. The block coefficient is to be calculated using the actual displacement determined from the hydrostatic data and using the total breadth of the structure and not just a single hull.

8.1.3 If, by using normal procedures, the minimum geometric summer freeboard determined is unreasonable for the operation of the craft, special consideration may be given, on a case by case basis, based on the proposed design configuration.

8.2 Structural configuration

8.2.1 The scantlings and arrangements indicated are for twin hulled craft. Craft with a greater number of hulls will be specially considered on the basis of the Rules.

8.3 Structural continuity

8.3.1 Structural members which contribute to the overall hull girder strength are to be carefully aligned so as to avoid discontinuities resulting in abrupt variations of stresses and are to be kept clear of any form of openings which may affect their structural performances.

8.3.2 Particular care is to be given to the continuity and alignment in way of the end connections of transverse bridging structures.

8.4 Cross-deck structure

8.4.1 For craft with multi-hulls linked by cross-deck structures, sufficient clearance is to be provided between the cross-deck structure and water surface to limit impact loads.

8.4.2 Where part or all of the cross-deck is intended to provide additional buoyancy to limit craft motion, the loading will be specially considered.

8.4.3 In the determination of the clearance, the following factors should be considered:

(a) Relative motion in waves.
(b) The wave generated between the hulls when running.
(c) The bow sinkage.

8.4.4 The submitted clearances must be validated either by calculations according to accepted theories, model test, full scale measurements or by documentary evidence if similar structures have proved to be satisfactory in service.

8.4.5 Where it is not possible to provide sufficient clearance to reduce the likelihood of slamming of the cross-deck structure, direct calculations or other appropriate means are to be used to assess the loads, assuming the most severe conditions for which the craft is to be approved.

8.5 Bulkheads

8.5.1 The number and arrangement of watertight and non-watertight bulkheads in the bridging structure will be specially considered dependent upon the structural configuration and size of the craft. Attention is drawn to the relevant requirements, e.g. structural fire protection and damaged stability, where these bulkheads are acting to prevent cross-flooding and the spread of smoke or flames.

8.6 Fore and aft ends

8.6.1 The forefoot and bow regions of fast craft that may be subjected to frequent impacts from flotsam are to be easily accessible for inspection. Access to the forepeak compartments may be provided through the forepeak bulkhead where access would otherwise be impracticable.

8.6.2 The aft end regions of all craft are to be easily accessible for inspections. Access may be provided through the aft peak bulkhead or by means of deck hatches or manholes.

8.7 Machinery spaces

8.7.1 Where an engine is fitted within a narrow hull, where engineroom temperatures may rise quickly, the ventilation requirements may require to be increased.

8.7.2 Within machinery spaces where space is limited access is to be provided for inspection.

8.8 Superstructures, deckhouses and bulwarks

8.8.1 Superstructures and deckhouses which enclose large flat open areas, that are subjected to racking loads and which may be of several tiers, are to be additionally stiffened with large web frames, partial bulkheads and pillars.

■ *Section 9* Navigation in ice

9.1 General

9.1.1 Where an ice class notation is to be included in the class of a craft, the scantlings will require to be specially considered. The additional requirements for operation in ice will, in general, be in accordance with LR's *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships), *Pt 8 Hull Construction in Composite*, where appropriate, and also *Pt 6, Ch 5, 7 Strengthening requirements for navigation in ice conditions*, *Pt 7, Ch 5, 7 Strengthening requirements for navigation in ice conditions* and *Pt 8, Ch 5, 6 Strengthening requirements for navigation in ice conditions* for steel, aluminium and composite construction respectively.

9.1.2 It is the responsibility of the Owner to determine which ice class notation is most suitable for their requirements.

9.1.3 The strengthening requirements detailed in this Section are applicable to craft, other than those assigned the notation **HSC** and/or **LDC** (*see Pt 1, Ch 2 Classification Regulations*), intended for operation in first-year ice conditions.

9.1.4 For a multi-hull craft, special consideration is to be given to the interaction of the ice between the hulls.

9.1.5 The requirements of this Section assume that, when approaching ice-infested waters, the craft's speed will be reduced appropriately. The vertical extent of ice strengthening for craft intended to operate in ice conditions at speeds exceeding 15 knots will be specially considered.

9.2 Ice belt

9.2.1 Side scuttles are not to be situated in the ice belt.

9.2.2 If the weather deck in any part of the craft is situated below the upper limit of the ice belt, the bulwark is to be reinforced to the same degree as the shell plating in the main ice belt.

9.3 Stern construction

9.3.1 A transom stern is not normally to extend below the ice load waterline. Where this cannot be avoided, the transom is to be kept as narrow as possible and the scantlings of plating and stiffeners are to be as required for the midcraft region.

9.4 Bossings and shaft struts

9.4.1 For craft with two or more propellers, shafting and sterntubes are generally to be enclosed within plated bossings. If detached supporting struts are necessary, their design, strengthening and attachment to the hull will be specially considered.

9.5 Powering of ice strengthened craft

9.5.1 For water jets, special consideration is to be given to the potential intake of ice pieces into the impeller causing additional loads and strengthening of steering buckets.

■ *Section 1*
General

1.1 Application

1.1.1 This Chapter applies to all the craft types detailed in the Rules, and requirements are given for rudders, nozzles, steering gear, bow and stern thrust unit structure and stabiliser structure.

1.2 General

1.2.1 The following symbols and definitions are applicable to this Chapter, unless otherwise stated:

σ_o = minimum yield stress or 0,5 per cent proof stress of the material, in N/mm^2 and is not to be taken greater than 0,7σ_T

where

σ_T = ultimate tensile strength of the material, in N/mm^2

1.2.2 The scantlings in aluminium alloy are to be obtained by multiplying the scantlings in mild steel, determined from this Chapter, by the following factors:

(a) Plating thickness factor = k_{ta}

where

$k_{ta} = \sqrt{k_{aa}}$

(b) Section modulus and cross sectional area factor, k_{aa}

where

k_{aa} = 235/σ_{ya} or 1,36, whichever is the greater

σ_{ya} = specified minimum yield stress or 0,2 per cent proof stress of aluminium alloy in the welded condition, in N/mm^2

1.3 Navigation in ice

1.3.1 Where an ice class notation is to be included in the class of a craft, the scantlings will require special consideration, *see Pt 3, Ch 2, 9 Navigation in ice*.

1.4 Materials

1.4.1 The requirements for materials are contained in the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials.

Section 2
Rudders

2.1 General

2.1.1 The scantlings of the rudder stock are to be not less than those required by *Table 3.2.6 Rudder stock diameter*.

2.1.2 For rudders having an increased diameter of rudder stock, *see Figure 3.2.1 Rudder types*, the increased diameter is to be maintained to a point as far as practicable above the top of the lowest bearing. This diameter may then be tapered to the diameter required in way of the tiller. The length of the taper is to be at least three times the reduction in diameter. Particular care is to be taken to avoid the formation of a notch at the upper end of the taper.

2.1.3 Sudden changes of section or sharp corners in way of the rudder coupling, jumping collars and shoulders for rudder carriers, are to be avoided.

2.2 Definition and symbols

2.2.1 Definitions and symbols for use throughout this Section are indicated in the appropriate tables.

2.3 Direct calculations

2.3.1 Where the rudder is of a novel design, high aspect ratio or the speed of the craft exceeds 45 knots the scantlings of the rudder and rudder stock are to be determined by direct calculation methods incorporating model test results and structural analysis, where considered necessary by LR.

2.4 Equivalents

2.4.1 Alternative methods of determining the loads will be specially considered, provided that they are based on model tests, full scale measurements or generally accepted theories. In such cases, full details of the methods used are to be provided when plans are submitted for approval.

2.5 Rudder arrangements

2.5.1 Rudders considered are the types shown in *Figure 3.2.1 Rudder types*, of double plate or single plate construction, constructed from steel, stainless steel or aluminium alloy. Other rudder types and materials will be subject to special consideration.

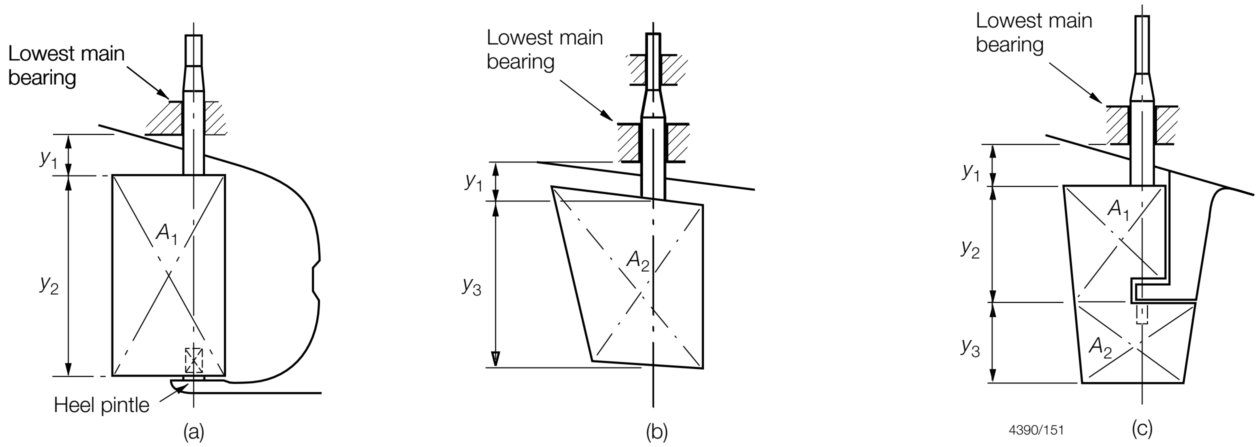


Figure 3.2.1 Rudder types

2.6 Rudder profile coefficient f_R

2.6.1 The rudder profile coefficient f_R for use in *Table 3.2.6 Rudder stock diameter* is to be as indicated in *Table 3.2.1 Rudder profile coefficient fR*.

Table 3.2.1 Rudder profile coefficient f_R

Design criteria (*see Figure 3.2.2 Rudder profiles*)	f_R ahead condition	f_R astern condition
Normal profile	1,0	0,97
Hollow profile	1,25	1,12
High lift profile	1,7	To be specially considered
Symbols		
f_R = rudder profile coefficient for use in *Table 3.2.6 Rudder stock diameter*		
Note Where a rudder is behind a fixed nozzle, the value of f_R given above, is to be multiplied by 1,3.		

2.7 Rudder position coefficient f_p

2.7.1 The rudder position coefficient, f_p, for use in *Table 3.2.6 Rudder stock diameter* is to be as indicated in *Table 3.2.2 Rudder position coefficient fp*.

Table 3.2.2 Rudder position coefficient f_p

Design criteria		f_p
Ahead condition	Rudder in propeller slipstream	0,248
	Rudder out of propeller slipstream	0,235
Astern condition		0,185
Bow rudder		0,226
Symbols		
f_p = rudder coefficient for use in *Table 3.2.6 Rudder stock diameter*		

2.8 Rudder speed coefficient f_v

2.8.1 The rudder speed coefficient, f_v, for use in *Table 3.2.6 Rudder stock diameter* is to be as indicated in *Table 3.2.3 Rudder speed coefficient f_v*.

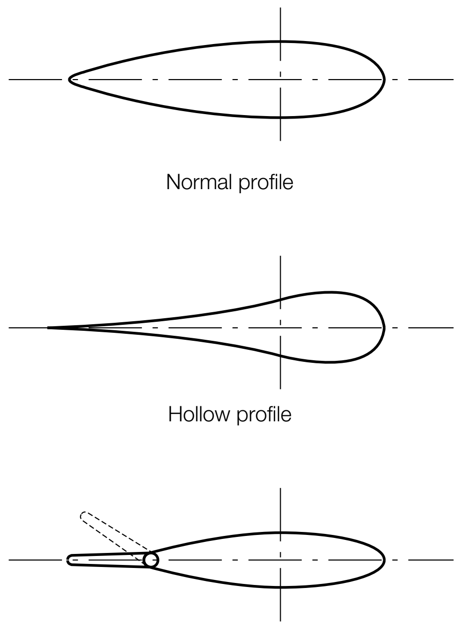


Figure 3.2.2 Rudder profiles

Table 3.2.3 Rudder speed coefficient f_v

Design criteria	f_V
Craft with $\dfrac{V}{\sqrt{L_{WL}}} < 3,0$	1,00
Craft with $\dfrac{V}{\sqrt{L_{WL}}} \geq 3,0$	1,12 - 0,005*V*
Symbols	
L_{WL} = as defined in *Pt 3, Ch 1, 6.2 Principal particulars 6.2.5* V = as defined in *Table 3.2.6 Rudder stock diameter* f_v = rudder speed coefficient for use in *Table 3.2.6 Rudder stock diameter*	

Table 3.2.4 Pintle arrangement coefficient *N*

Support arrangement	Value of *N*
Two or more pintles Upper stock	*N*=0
One or no pintle	$N = A_1(0,67y_1 + 0,17y_2) - A_2(y_1 + 0,5y_3)$
Symbols	

N =	coefficient for use in *Table 3.2.6 Rudder stock diameter*
A_1,A_2 =	part rudder areas, in m^2, *see Figure 3.2.1 Rudder types*
y_1 y_2 y_3 =	vertical dimensions, in metres, *see Figure 3.2.1 Rudder types*
Any values of y and A not indicated in *Figure 3.2.1 Rudder types* are to be taken as zero.	
NOTE If, in semi-spade (Mariner) type rudders, the pintle is housed above the rudder horn gudgeon and not shown in *Figure 3.2.1 Rudder types*, y_2 and y_3 are to be measured to the top of the gudgeon.	

2.9 Pintle arrangement coefficient *N*

2.9.1 The pintle arrangement coefficient, N, for use in *Table 3.2.6 Rudder stock diameter* is to be as indicated in *Table 3.2.4 Pintle arrangement coefficient N* .

Table 3.2.5 Position of centre of pressure

Design criteria	Value of x_{PF} and x_{PA} to be used in *Table 3.2.6 Rudder stock diameter*		
Rectangular rudders;			
(a) Ahead condition	x_{PF}	=	($0{,}33ex_B$-x_L), but not less than $0{,}12x_B$
(b) Astern condition	x_{PA}	=	(x_A- $0{,}25x_B$), but not less than $0{,}12x_B$
Non-rectangular rudders;			
(a) Ahead condition	x_{PF}	=	as calculated from geometric form (*see* Note) but not less than: $\frac{0,12A_R}{y_R}$
(b) Astern condition	x_{PA}	=	as calculated from geometric form (*see* Note) but not less than: $\frac{0,12A_R}{y_R}$
Symbols			
x_{PF} =	horizontal distance from the centreline of the rudder pintles, or axle, to the centre of pressure in the ahead condition, in metres		
x_{PA} =	horizontal distance from the centreline of the rudder pintles, or axle, to the centre of pressure in the astern condition, in metres		
x_B =	breadth of rudder, in metres		
y_R =	depth of rudder at centreline of stock, in metres		
A_R =	rudder area, in m^2		
x_L and x_A =	horizontal distances from leading and after edges, respectively, of the rudder to the centreline of the rudder pintles, or axle, in metres		
x_S =	horizontal length of any rectangular strip of rudder geometric form, in metres		

e = hull form factor at ahead condition for $L < 65$ m , $e = 1{,}0$ for $L \geq 65$ m, $e = 2\left(C_b + 10\frac{B}{L_R} - 2\right)\frac{V}{\sqrt{L_R}}$ or $e = 1 + \left(\frac{L_R - 65}{70}\right)$ whichever is the lesser, but not less than 1,0 and need not be taken greater than 1,5 L_R, B and C_b are as defined *Pt 3, Ch 1, 6.2 Principal particulars* is as defined in *Table 3.2.6 Rudder stock diameter*
NOTE For rectangular strips the centre of pressure is to be assumed to be located as follows: (a) 0,33ex_S abaft leading edge of strip for ahead condition. (b) 0,25x_S from aft edge of strip for astern condition.

2.10 Centre of pressure

2.10.1 The position of centre of pressure for use in *Table 3.2.6 Rudder stock diameter* is to be as indicated in *Table 3.2.5 Position of centre of pressure*.

2.11 Rudder stock (tubular)

2.11.1 Tubular rudder stock scantlings are to be not less than that necessary to provide the equivalent strength of a solid stock as required by *Table 3.2.6 Rudder stock diameter*, and can be calculated from the following formula:

$$d_E = \sqrt[3]{\frac{d_1^{\,4} - d_2^{\,4}}{d_1}}$$

where

d_E = the diameter of the equivalent solid rudder stock, in mm

d_1, d_2 = external and internal diameters, respectively of the tubular stock, in mm

Table 3.2.6 Rudder stock diameter

Requirement
1. Basic stock diameter, d_s, at and below lowest bearing: $$d_s = f_c f_p f_v \sqrt[3]{\left(\frac{235}{\sigma_0}\right)^m f_R \left(V + 3\right)^2 \sqrt{A_R^2 x_P^2 + N^2}} \quad \text{mm}$$
2. Diameter in way of tiller, d_{SU}: d_{SU} = d_s calculated from (1) with N=0
3. Lateral force on rudder acting at centre of pressure of blade, P_L: $$P_L = \left(\frac{f_p}{0{,}248}\right)^3 \frac{(V + 3)^2 A_R f_R}{10} \text{ kN}$$

Symbols
f_c = 79 for craft of Rule length, L_R, 50 m and below varying up to 83,3 at a Rule length, L_R, of 70 m. Intermediate values to be obtained by interpolation = 83,3 for craft of Rule length, L_R, 70 m and above f_p = rudder position coefficient, *see Table 3.2.2 Rudder position coefficient fp* f_v = rudder speed coefficient, *see Table 3.2.3 Rudder speed coefficient f_v* f_R = rudder profile coefficient, *see Table 3.2.1 Rudder profile coefficient fR* m = 0,75 for $\sigma_0 > 235$ = 1,0 for $\sigma_0 \leq 235$ σ_0 = minimum yield stress, in N/mm^2, of material used, and is not to be taken greater than 0,7 σ_T σ_T = ultimate tensile strength of the material used, in N/mm^2 V = the maximum speed for the astern and ahead condition, in knots. In no case to be less than 5 knots A_R = rudder area, in m^2 x_P = x_{Pa} or x_{Pf}, for the astern and ahead condition respectively, *see Table 3.2.5 Position of centre of pressure* N = coefficient dependent on rudder support arrangement, *see Table 3.2.4 Pintle arrangement coefficient N*
Note Where higher tensile steel is used for the rudder stock, σ_0 is not to be taken as greater than 450 N/mm^2.

2.12 Single plate rudders

2.12.1 The scantlings of a single plate rudder are to be not less than required by *Table 3.2.7 Single plate rudder construction*, *see also Pt 3, Ch 3, 2.5 Rudder arrangements 2.5.1*.

2.12.2 Rudder arms are to be efficiently attached to the mainpiece.

Table 3.2.7 Single plate rudder construction

Item	Requirement
Blade thickness	$t_B = 0{,}0015 V y_W + 2{,}5$ mm with a minimum of 10 mm
Arms	Spacing ≤ 1000mm $Z_A = 0{,}0005 V^2 x_a^2 y_W$ cm^3
Mainpiece	Diameter = d_s mm For spade rudders, the lower third may taper down to 0,75d_s mm

Symbols
t_B = blade thickness, in mm
y_W = vertical spacing of rudder arms, in mm
V = maximum speed, in knots, as defined in *Table 3.2.6 Rudder stock diameter*
x_a = horizontal distance from the aft edge of the rudder to the centre of the rudder stock, in metres
z_A = section modulus of arm, in cm^3

2.13 Double plate rudders

2.13.1 The scantlings of a double plated rudder are to be not less than required by *Table 3.2.8 Double plated rudder construction*.

2.13.2 In way of rudder couplings and heel pintles the plating thickness is to be suitably increased.

2.13.3 On semi-spade (Mariner) type rudders a notch effect in the corners in the bottom pintle region is to be avoided (*see* AA, *Figure 3.2.3 Semi-spade (mariner) type rudder*). An insert plate, 1,6 times the Rule thickness of the side plating, is to be fitted at this position, extending aft of the main vertical web and having well rounded corners. The main vertical web is to be continuous over the full depth of the rudder and have a thickness not less than three times the thickness required by *Table 3.2.8 Double plated rudder construction*, Item (4). Where an additional continuous main vertical web is arranged to form an efficient box structure, the webs are to have a thickness not less than required by *Table 3.2.8 Double plated rudder construction*, Item (4).

2.13.4 Adequate hand or access holes are to be arranged in the rudder plating in way of pintles as required, and the rudder plating is to be reinforced locally in way of these openings. Continuity of the modulus of the rudder mainpiece is to be maintained in way of the openings.

Table 3.2.8 Double plated rudder construction

Item	Requirement
(1) Side plating	$t_S = \beta\, F_a(0,003 y_W + 2,03)(1,45 + 0,1\sqrt{d_s})$ mm
(2) Webs - vertical and horizontal	$t_W = t_s$ mm
(3) Top and bottom plates and nose plates	As (1) above $t_N = t_S + 2$ mm
(4) Mainpiece	Stress due to bending ≤ 78,0 N/mm^2

Symbols

β = A_a (1-0,25A_a)

A_a = panel aspect ratio, but is not to be taken as greater than 2,0

F_a = 1,0 for mild steel, 0,95 for aluminium alloy and 0,9 for stainless steel. Other materials will be specially considered.

y_w = vertical spacing, in mm, of the horizontal webs or arms, but is not to exceed 900 mm

d_s = basic stock diameter, given by *Table 3.2.6 Rudder stock diameter*, in mm

t_N = thickness, in mm, of top and bottom plates and nose plate

t_S = thickness, in mm, of side plating

t_W = thickness, in mm, of webs

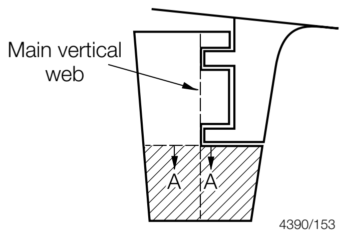


Figure 3.2.3 Semi-spade (mariner) type rudder

2.13.5 Connection of rudder side plating to vertical and horizontal webs, where internal access for welding is not practicable, is to be by means of slot welds onto flat bars on the webs. The slots are to have a minimum length of 75 mm and in general, a minimum width of twice the side plating thickness. The ends of the slots are to be rounded. The space between the slots is not to exceed 150 mm and welding is to be based on a weld factor of 0,44.

2.13.6 For testing of rudders, *see Table 1.7.1 Testing requirements* in Chapter 1.

2.13.7 Where the fabricated mainpiece of a spade rudder is connected to the horizontal coupling flange by welding, a full penetration weld is required.

2.14 Composite rudders

2.14.1 The requirements in this section are based on spade rudder constructions of composite material with an aspect ratio not less than 3,0. Requirements for rudders with a lesser aspect ratio will be specially considered. Requirements for rudders made from a metal stock and composite blade will be specially considered. Requirements for rudder arrangements with pintles will be specially considered.

2.14.2 The requirements in this section are based on construction using carbon/epoxy composite but can be used for alternative constructions using other reinforcement and matrix materials with due consideration for the properties of these materials.

2.14.3 The requirements in this section are based on a structural arrangement with a single stock of generally rectangular or trapezoid shape, extending from the upper bearing through the lower bearing, down to not less than 0,75 times the height of the rudder blade from the upper edge of the rudder blade. In this arrangement, the blade is moulded around a core made of structural foam bonded to the fore and aft side of the stock. The foam transfers the shear load to the stock. The bending in the horizontal plane is taken by the skin of the blade.

2.14.4 The requirements are based on the stock being built from interleaved layers of unidirectional fibres providing bending strength and biaxial fibres to provide torsion and shear strength, wrapped around a foam core.

2.14.5 The limiting stress fraction, f_σ, to be used in the design is 0,25.

2.14.6 At and below the lower bearing, at any section along the length of the stock the amount of biaxial material is to be sufficient to withstand the combined action of shear load and torsion without exceeding the limiting stress fraction. The shear load can be taken as:

Q_{bs} = (f_p/0.248)^3 * (V+3)^2*A_{rt}*f_R/10 kN

Where

A_{rt} = area of rudder blade between the position of the section and the lower end of the rudder, in m^2

The torsion can be taken as:

T_{bs} = Q_{bs}*x_{pbs} kNm

with

x_{pbs} = x_{pa} as in *Table 3.2.4 Pintle arrangement coefficient N* , calculated for the area of the rudder blade below the section under consideration.

V, f_p, f_R *see Table 3.2.5 Position of centre of pressure*

2.14.7 At and below the lower bearing, at any section along the length of the stock the amount of unidirectional material is to be sufficient to withstand the combined action of bending moment, shear load and torsion without exceeding the limiting stress fraction. The bending moment can be taken as:

M_{bs} = Q_{bs} * y_a kNm

where

y_a = distance between the position of the section and the centroid of the rudder area below the section, in metres.

2.14.8 At and above the lower bearing, at any section along the length of the stock the amount of biaxial material is to be sufficient to withstand the combined action of shear load and torsion without exceeding the limiting stress fraction. The position of the tiller is to be considered.

The shear load to be considered can be taken as the reaction force in the upper bearing.

F_{ub} = Q_{bl} * (y_1+(y_3+h_b)/2)/d_{yb} kN

where

y_3 is defined as in *Figure 3.2.1 Rudder types*
F_{bl} is Q_{bs} taken at the lower bearing position.
d_{yb} is the vertical distance centre to centre between the upper and lower bearing.
h_b is height of lower bearing.

The torsion load can be taken as the torsion load in way of the lower bearing.

2.14.9 At and above the lower bearing, at any section along the length of the stock the amount of unidirectional material is to be sufficient to withstand the combined action of bending moment, shear load and torsion without exceeding the limiting stress fraction. The bending moment can be taken as:

M_{bs} = F_{ub} * y_u kNm

where

y_u = distance between the position of the section and the centroid of the upper bearing, in metres.

2.14.10 The laminate in way of the mounting position of the tiller is to be suitably protected and reinforced where necessary to take the loads from the tiller.

2.14.11 The shear strength of the foam and the bonding to the stock are to be not less than:

q_{bs} = (f_p/0.248)^3 * (V+3)^2*f_R/10 * b_b/b_s N/mm^2

where

b_b = local width of blade outside the stock, *see Figure 3.2.4 Composite rudder dimensions*

b_s = width of the stock or width of bonding to stock, *see Figure 3.2.4 Composite rudder dimensions*, whichever is less.

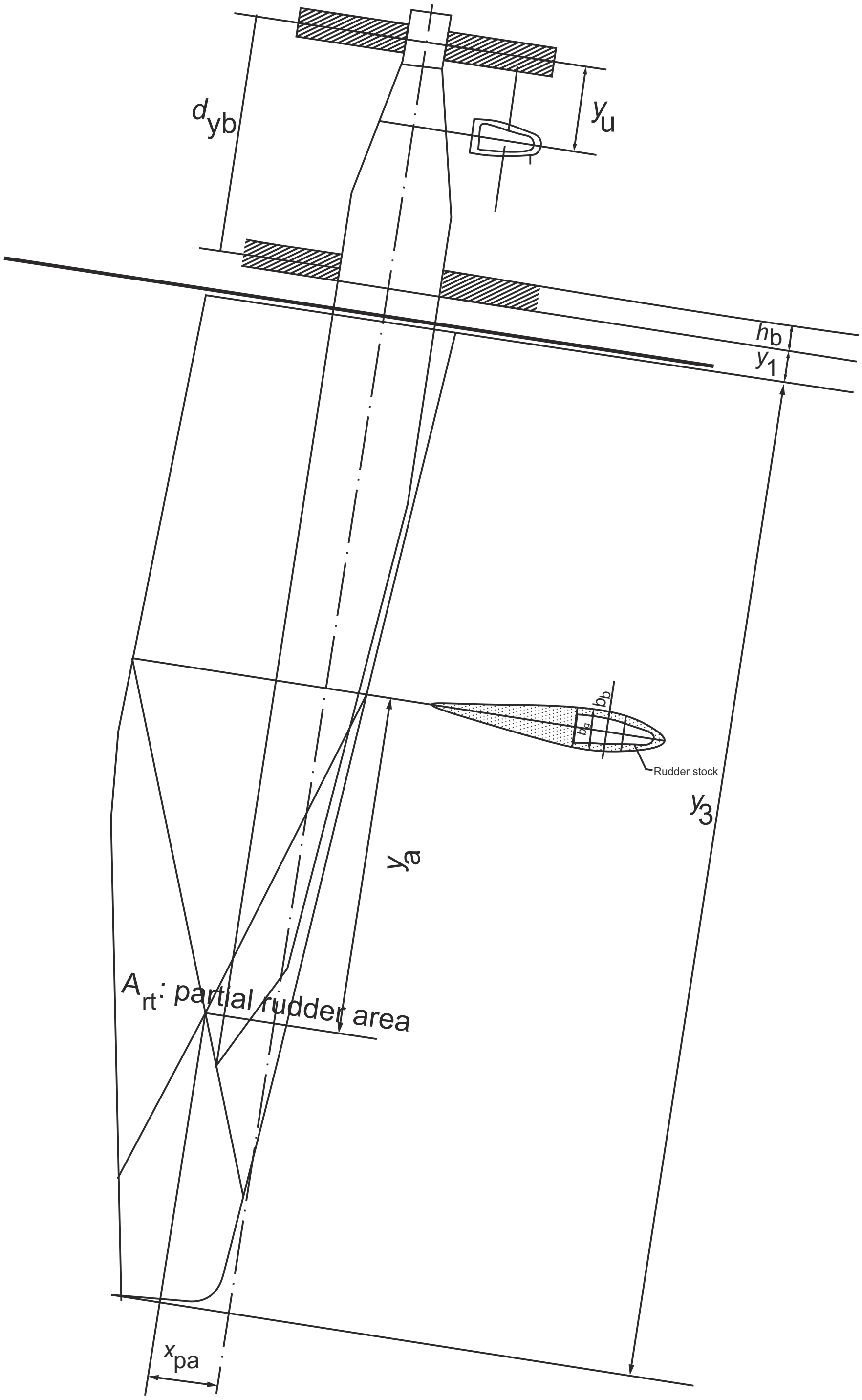


Figure 3.2.4 Composite rudder dimensions

2.14.12 The laminate of the skin of the blade is determined by the envelope of the following criteria:

- tensile stress due to load carried to stock
- compressive stress due to load carried from blade to stock
- wrinkling under this compressive stress
- minimal weight of reinforcement criterion as for shell laminate.
- below the lower end of the stock, strength required to support the part of the blade below.

2.14.13 The lower end of the blade, extending below the stock, can be executed as a sacrificial piece to save the stock in case of grounding.

2.15 Cast metal rudders

2.15.1 Where rudders are cast, the mechanical and chemical properties of the metal are to be submitted for approval. If the rudder stock is cast integral with the rudder blade, abrupt changes of section and sharp corners are to be avoided.

2.16 Lowest main bearing requirement

2.16.1 The design of the lowest bearing is to comply with the requirements of *Table 3.2.9 Lowest main bearing requirements*.

Table 3.2.9 Lowest main bearing requirements

Item	Requirement	
Lowest main bearing	Depth Z_B, in mm $1,5d_s \geq Z_B \geq 1,0d_s$	Minimum bearing housing wall thickness, in mm lesser of $0,2d_s$ or 100
Bearing pressure (on the projected area of the lowest main bearing), where the projected area is to be taken as the length x diameter	Bearing material	Maximum pressure, in N/mm^2 *see* Note 4
	Metal	7,0
	Synthetic	5.5
Clearance in lowest main bearing on the diameter (note should be taken of the manufacturer's recommended clearances, particularly where bush material requires pre-soaking)	Bearing material	Minimum clearance, in mm *see* Note 3
	Metal, *see* Note 2	$0,001d_s + 1,0$
	Synthetic	$0,002d_s + 1,0$ but not less than 1,5
Symbols		
d_s = stock diameter, given by *Table 3.2.6 Rudder stock diameter*, in mm		
Note 1. Where web stiffening is fitted on the bearing, a reduction in wall thickness will be considered.		
Note 2. For bearings which are pressure lubricated the clearance must be restricted to enable the pressure to be maintained.		
Note 3. Value of proposed minimum clearance is to be indicated on plans submitted for approval.		
Note 4. Proposals for higher pressures or other materials will be specially considered on the basis of satisfactory test results.		

2.17 Bearings

2.17.1 Bearings are to be of approved materials and effectively secured to prevent rotational and axial movement.

2.17.2 Where it is proposed to use stainless steel for liners or bearings for rudder stocks and/or pintles, the chemical composition is to be submitted for approval. Where the two surfaces are stainless steel materials, they should have suitable resistance to galling. When stainless steel material is used, arrangements to ensure an adequate supply of seawater to the bearing are to be provided to protect against stagnant sea-water initiated corrosion.

2.17.3 Synthetic rudder bearing materials are to be of a type approved by LR.

2.17.4 When roller bearings are used on the rudder stock, the bearing must be of a size, material and type suitable to sustain the loads from the rudder. Arrangement must be made in the design to make them watertight.

2.18 Liners

2.18.1 Where liners are fitted to rudder stocks or pintles, they are to be shrunk on or otherwise efficiently secured.

2.18.2 Where it is proposed to use stainless steel liners, the requirements in *Pt 3, Ch 3, 2.17 Bearings 2.17.2* are to be complied with.

2.18.3 When stainless steel liners are used, arrangements to ensure an adequate supply of sea-water to the liner are to be provided.

2.19 Pintles

2.19.1 Rudder pintles and their bearings are to comply with the requirements of *Table 3.2.10 Pintle requirements*.

2.19.2 Where the lower pintle is housed above the rudder gudgeon *see Figure 3.2.5 Lower pintle housed above rudder gudgeon*, and not below as shown in *Figure 3.2.6 Lower pintle housed below rudder gudgeon*, C_{PL} is to be measured to the top of the gudgeon.

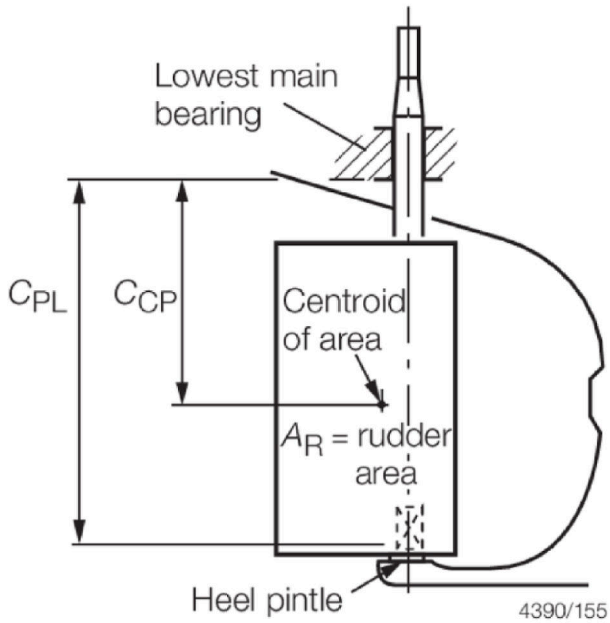


Figure 3.2.5 Lower pintle housed above rudder gudgeon

Table 3.2.10 Pintle requirements

Item	Requirement	
(1) Pintle diameter, *see* Note 2	$\delta_{PL} = \sqrt{\left(\frac{235}{\sigma_o}\right)^m}\left(31 + 4,17V\sqrt{A_{PL}}\right)$ mm For single pintle rudders and lower pintle of semi-spade rudders: $A_{PL} = \frac{A_R C_{CP}}{C_{PL}}$ m^2 but for semi spade rudders need not be taken greater than A_R Upper pintle on semi-spade rudders: $A_{PL} = A_R\left(1 - \frac{C_{CP}}{C_{PL}}\right)$m^2 or $0,35A_R$ m^2, whichever is the greater For rudders with two or more pintles (except semi-spade rudders): $A_{PL} = \frac{A_R}{N_{PL}}$ m^2	
(2) Maximum pintle taper	Method of assembly	Taper (on diameter)
	Manual assembly, key fitted (pintle ≤ 200mm diameter)	1 in 6
	Manual assembly, key fitted (pintle ≤ 400mm diameter)	1 in 9
	For keyed and other manually assembled pintles with diameters between 200mm and 400mm, the taper is to be obtained by interpolation.	
	Hydraulic assembly, dry fit Hydraulic assembly, oil injection	1 in 12 1 in 15
(3) Bearing length	$Z_{PB} \geq 1,2\delta_{PL}$ mm May be less for very large pintles if bearing pressure is not greater than that given in (4), but Z_{PB} must not be less than $1,0\delta_{PL}$ mm	

(4) Bearing pressure (on projected area)	Bearing material	Pressure
	Metal Synthetic	7,0 N/mm^2 5,5 N/mm^2
	Using force acting on bearing: $P_{PL} = \frac{A_{PL}(V+3)^2 f_R}{10}$ kN A_{PL} as for item (1)	
(5) Gudgeon thickness in way of pintle (measured outside bush if fitted)	$b_G \geq 0,5\,\delta_{PL}$ but need not normally exceed 125mm	
(6) Pintle clearance (note should be taken of the manufacturer's recommended clearances particulary where bush material requires pre-soaking). Value of proposed minimum clearance is to be indicated on plans submitted for approval.	Bearing material	Minimum clearance, mm
	Metal Synthetic	$0,001\delta_{PL}$ + 1,0 $0,002\delta_{PL}$ + 1,0 but not less than 1,5

Symbols

δ_{PL} = pintle diameter, in mm

V = as defined in *Table 3.2.6 Rudder stock diameter* but not less than 10 knots

A_{PL} = rudder area supported by the pintle, in m^2

C_{CP}, C_{PL} = dimensions in metres, as indicated in *Figure 3.2.5 Lower pintle housed above rudder gudgeon* and *Figure 3.2.6 Lower pintle housed below rudder gudgeon*

A_R = rudder area, in m^2

σ_o = as defined in *Table 3.2.6 Rudder stock diameter*

N_{PL} = number of pintles on the rudder

Z_{PB} = pintle bearing length, in mm

P_{PL} = force acting on bearing, in kN

b_G = thickness of gudgeon material in way of pintle, in mm

f_R = rudder profile coefficient, *see Table 3.2.1 Rudder profile coefficient fR*

m = as defined in *Table 3.2.6 Rudder stock diameter*

Note 1. Proposals for higher pressures or other materials will be specially considered on the basis of satisfactory test results.

Note 2. The length of the pintle housing in the gudgeon is not to be less than the maximum pintle diameter.

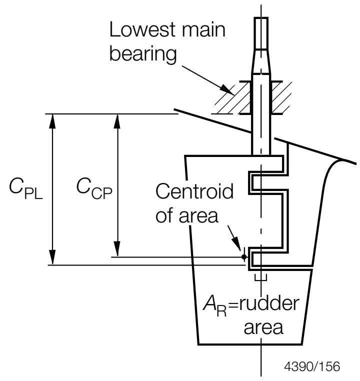


Figure 3.2.6 Lower pintle housed below rudder gudgeon

2.19.3 Special attention is to be paid to the fit of the pintle taper into its socket. To facilitate removal of the pintles, it is recommended that the taper is to be not less than half the maximum value given in *Table 3.2.10 Pintle requirements*.

2.19.4 The distance between the lowest rudder stock bearing and the upper pintle is to be as short as possible.

2.19.5 Where liners are fitted to pintles, they are to be shrunk on or otherwise efficiently secured. If liners are to be shrunk on, the shrinkage allowance is to be indicated on the plans. Where liners are formed by stainless steel weld deposit, the pintles are to be of weldable quality steel and details of the procedure are to be submitted.

2.19.6 The bottom pintle on semi-spade (Mariner) type rudders are:

(a) If inserted into their sockets from below, to be keyed to the rudder or sternframe as appropriate or to be hydraulically assembled, with the nut adequately locked, or
(b) If inserted into their sockets from above, to be provided with an appropriate locking device, the nut being adequately secured.

2.19.7 Where an ***IWS** (In-water Survey) notation is to be assigned, *see Pt 3, Ch 3, 2.37 In-water Survey requirements*.

2.19.8 Where it is proposed to use stainless steel liners, the requirements in *Pt 3, Ch 3, 2.17 Bearings 2.17.2* are to be complied with.

2.20 Bolted couplings

2.20.1 Rudder coupling design is to be in accordance with *Table 3.2.11 Rudder couplings to stock*.

Table 3.2.11 Rudder couplings to stock

Arrangement	Parameter	Requirement	
		Horizontal coupling	Vertical coupling
(1) Bolted couplings (*see* Notes)	n	≥ 6	≥ 8
	δ_b	$\dfrac{0,65 d_s}{\sqrt{n}}$	$\dfrac{0,81 d_s}{\sqrt{n}}$
	m	$0,00071 n d_s \delta_b^2$	$0,00043 d_s^3$
	t_f	δ_b *see* Note 1	δ_b
	α_{max} *see* Note 2	$\left(53,82 - 35,29 k_1\right)\dfrac{d_s^3}{P_L h 10^6} - \left(1,8 - 6,3\dfrac{R}{d_s}\right)\dfrac{t_f - t_{fa}}{t_{fa}}$	-
	$\alpha_{as\ built}$ *see* Note 2	$\leq \alpha_{max}$	-
	w_f	$0,67\delta_b$	$0,67\delta_b$
(2) Conical couplings	θ_t	$\leq \dfrac{1}{K_1}$	
	l_t	$\geq 1,5 d_s$	
	$\overline{p}$	$\dfrac{P_R \theta_t \overline{\delta}_{ST} + 4M_T\sqrt{K_2\left(\left(\left(\dfrac{P_R \overline{\delta}_{ST}}{2M_T}\right)^2 + 1\right) - \left(\dfrac{\theta_t}{2}\right)^2\right)}}{5,03\, \overline{\delta}_{ST}^2 l_t\left(K_2 - \left(\dfrac{\theta_t}{2}\right)^2\right)}$	
	w	$\dfrac{9,6 \times 10^{-6}\overline{p}\, \overline{\delta}_{ST}}{\theta_t\left(1 - \overline{f}^2\right)}$	
	P_u	Approximately equal to $0,8\pi\, \overline{p} l_t \overline{\delta}_{ST}\left(K_3 + \dfrac{\theta_t}{2}\right)$	
	P_o	Approximately equal to $2,83\, \overline{p} l_t \overline{\delta}_{ST}\left(K_3 - \dfrac{\theta_t}{2}\right)$	
	σ_o	$\geq \dfrac{12,35 \times 10^4 w \theta_t \sqrt{3 + f^4}}{\delta_{ST}}$	
Symbols			
n = number of bolts in coupling			
δ_b = diameter of coupling bolts, in mm			
d_s, d_{su} = rudder stock diameters as defined in *Table 3.2.6 Rudder stock diameter*			

m = first moment of area of bolts about centre of coupling, in cm^3

k_1 = the greater of k_s and k_f

k_s = $\left(\frac{235}{\sigma_o}\right)^m$ where σ_o is the specified minimum yield stress at the rudder stock and m is as defined in *Table 3.2.6 Rudder stock diameter*

k_f = $\left(\frac{235}{\sigma_o}\right)^m$ where σ_o is the specified minimum yield stress at the upper coupling flange and *m* is as defined in *Table 3.2.6 Rudder stock diameter*

h = vertical distance between the centre of pressure and the centre point of the palm radius, *R*, in metres, *see Figure 3.2.7 Rudder stock connection*

R = palm radius between rudder stock and connected flange, not smaller than $\frac{d_s}{10}$, in mm

t_f = minimum thickness of coupling flange, in mm

t_{fa} = as built flange thickness, in mm

α_{max} = maximum allowable stress concentration factor

$\alpha_{as\ built}$ = stress concentration factor for as built scantlings

= $\frac{0,73}{\sqrt{\frac{R}{d_s}}}$

w_f = width of flange material outside the bolt holes, in mm

θ_t = taper of conical coupling, on the diameter, e.g.:

= $\theta_t = \frac{1}{15} = 0,067$

l_t = length of taper, in mm

$\overline{p}$ = required mean grip stress, in N/mm^2

w = corresponding push-up of rudder stock, in mm

P_u, P_o = corresponding push-up, pull-off loads respectively, in N

σ_o = minimum yield stress of stock and gudgeon material, in N/mm^2. σ_o is not to be taken greater than 70 per cent of the ultimate tensile strength

P_R = effective weight of rudder, in N

$\overline{\delta}_{ST}$ = mean diameter of coupling taper, in mm

δ_{ST} = diameter of coupling taper at any position, in mm

$\overline{\delta}_{GH}$ = mean external diameter of gudgeon housing, in mm

δ_{GH} = external diameter of gudgeon housing at any position, in mm

$\overline{f} = \dfrac{\overline{\delta}_{ST}}{\overline{\delta}_{GH}}$

$f = \dfrac{\delta_{ST}}{\delta_{GH}}$

M_T = maximum torque applied to stock, and is to be taken as the greater of M_F, M_A or M_W.

M_F = $P_L X_{PF} \times 10^6$ Nmm in the ahead condition

M_A = $P_L X_{PA} \times 10^6$ Nmm in the astern condition

M_W = the torque generated by the steering gear at the maximum working pressure supplied by the manufacturer, in Nmm. M_W is not to exceed the greater of 3,0M_F or 3,0M_A

P_L = lateral force on rudder acting at centre of pressure in ahead and astern conditions, as defined in *Table 3.2.6 Rudder stock diameter*, in kN

X_{PF}, X_{PA} = the horizontal distances, in metres, *see Table 3.2.5 Position of centre of pressure*

K_1, K_2, K_3 = constants depending on the type of assembly adopted as follows:

		K_1	K_2	K_3
Oil injection method	with key	15	0,0064	0,025
Oil injection method	without key	15	0,0036	0,025
Dry fit method	with key	12	0,0128	0,170
Dry fit method	without key	12	0,0072	0,170

Note 1. For spade rudders with horizontal coupling, t_f is not to be less than 0,25d_s.

Note 2. This requirement is applicable only for spade rudders with horizontal couplings, *see Figure 3.2.7 Rudder stock connection*.

Note 3. Where materials vary for individual components, scantling calculations for such components are to be based on d_s for the relevant material.

2.20.2 Where coupling bolts are required they are to be fitted bolts. Suitable arrangements are to be made to lock the nuts.

2.20.3 For rudders with horizontal coupling arrangements, where the upper flange is welded to the rudder stock, a full penetration weld is required and its integrity is to be confirmed by non-destructive examination. Such rudder stocks are to be

subjected to a furnace post-weld heat treatment (PWHT) after completion of all welding operations. For carbon or carbon manganese steels, the PWHT temperature is not to be less than 600°C.

2.20.4 The connecting bolts for coupling the rudder to the rudder stock are to be positioned with sufficient clearance to allow the fitting and removal of the bolts and nuts without contacting the palm radius, *R*, *see Figure 3.2.7 Rudder stock connection*. The surface forming the palm radius is to be free of hard and sharp corners and is to be machined smooth to the Surveyor's satisfaction. The surface in way of bolts and nuts is to be machined smooth to the Surveyor's satisfaction.

2.20.5 For spade rudders fitted with a fabricated rectangular mainpiece, the mainpiece is to be designed with its forward and aft transverse sections at equal distances forward and aft of the rudder stock transverse axis, *see Figure 3.2.7 Rudder stock connection*.

2.21 Conical couplings

2.21.1 Where a rudder stock is connected to a rudder by a keyless fitting, the rudder is to be a good fit on the rudder stock cone. During the fit-up, and before the push-up load is applied, an area of contact of at least 80 per cent of the theoretical area of contact is to be achieved, and this is to be evenly distributed. The relationship of the rudder to stock at which this occurs is to be marked, and the push-up then measured from that point. The upper edge of the upper mainpiece bore is to have a slight radius. After final fitting of the stock to the rudder, positive means are to be used for locking the securing nut to the stock.

2.21.2 Where a keyed tapered fitting of a rudder stock to a rudder is proposed, a securing nut of adequate proportions is to be provided. After the final fitting of the stock to the rudder, positive means are to be used for locking this nut.

2.22 Rudder carrier arrangements

2.22.1 The weight of the rudder is to be supported at the heel pintle or by a carrier attached to the rudder head. The hull structure supporting the carrier bearing is to be adequately strengthened. The plating under all rudder-head bearings or rudder carriers is to be increased in thickness.

2.23 Anti-jump collars

2.23.1 Suitable arrangements are to be provided to prevent the rudder from lifting.

2.23.2 Jumping collars are not to be welded to the rudder stock.

2.24 Drain plugs

2.24.1 Where rudders are of plated construction, drain plugs are to be provided to ensure that all compartments can be adequately drained. These plugs are to be locked and details of their scantlings, arrangements and position clearly indicated on the rudder plan.

2.25 Corrosion protection

2.25.1 All metalwork is to be suitably protected against corrosion. This may be by coating or, where applicable, by a system of cathodic protection, *see Ch 15 Corrosion Prevention* of the Rules for Materials.

2.25.2 Metalwork is to be suitably cleaned before the application of any coating. Where appropriate, blast cleaning or other equally effective means are to be employed for this purpose.

2.26 Dissimilar materials

2.26.1 Where materials vary for individual components, they are to be compatible to avoid galvanic corrosion. Scantling calculations for the components are to be based on d_s for the relevant material, *see Table 3.2.6 Rudder stock diameter*.

2.27 Internal coatings

2.27.1 Internal surfaces of the rudder are to be efficiently coated or the rudder is to be filled with foam plastics. Where it is intended to fill the rudder with plastic foam, details of the foam are to be submitted.

2.28 Pressure testing

2.28.1 For testing of rudders, *see Table 1.7.1 Testing requirements* in Chapter 1.

2.29 Tiller arms, quadrants

2.29.1 Tillers and quadrants are to comply with the requirements of *Table 1.4.1 Connection of tiller to stock* in Pt 14, Ch 1.

2.29.2 The steering gear is to be mounted on a seat and adequately secured.

2.30 Connecting bars

2.30.1 Connecting bars are to comply with the requirements of *Pt 14, Ch 1, 4.3 Rudder systems 4.3.3*.

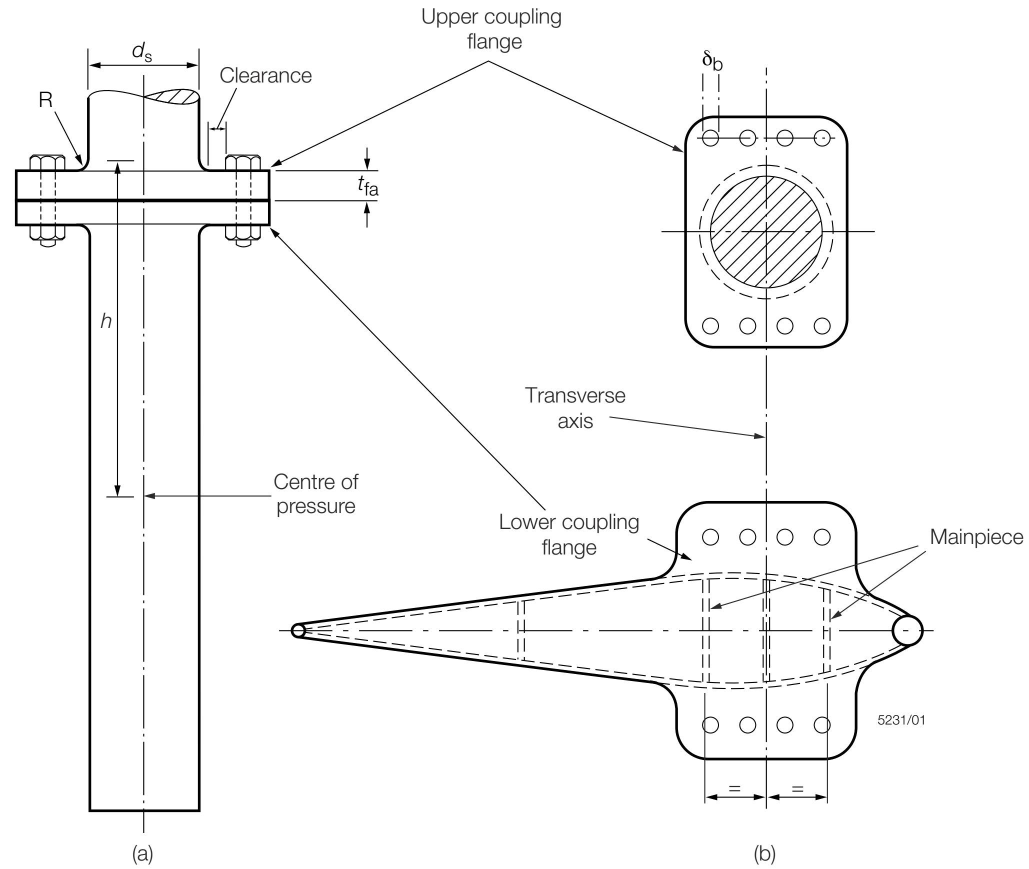


Figure 3.2.7 Rudder stock connection

2.31 Keys and keyways

2.31.1 Where the tiller or quadrant is bolted, a key having an effective cross-sectional area in shear of not less than $0,25d_{SU}^2$ mm^2 is to be fitted. The thickness of the key is to be not less than $d_{SU}/6$ mm. Alternatively, the rudder stock may be machined to a square section in lieu of fitting a key. d_{SU} is as defined in *Table 3.2.6 Rudder stock diameter*.

2.31.2 Keyways are to extend over the full depth of the tiller boss.

2.31.3 Keyways in the rudder stock are to have rounded ends and the corners at the base of the keyway are to be radiused.

2.32 Stopping arrangements

2.32.1 Suitable rudder stops are to be provided to limit the rudder angle to the desired level port and starboard. These stops are to be of substantial construction and efficiently connected to the supporting structure.

2.33 Novel designs

2.33.1 Where rudders are of a novel design they may be specially considered on the basis of the Rules. Alternatively the Builder's/designer's calculations are to be submitted for consideration.

2.34 FRP double plated rudders

2.34.1 FRP double plated rudders are to have an internal structure of suitable strength and material. Details of the rudder are to be submitted to LR for approval.

2.34.2 Where rudder blades are moulded in halves they are to be effectively joined together by means of external overbonding of the joint or suitable mechanical fastening or equivalent.

2.34.3 The internal structure of FRP double plated rudders may be a metallic framework. It is to be made up of a mainpiece fitted with arms, within the blade, or an equivalent arrangement. Both halves of the rudder blade moulding are to be effectively connected to the metallic framework and mainpiece by either mechanical means or suitable bonded connection.

2.34.4 When the internal structure of the FRP double plated rudder is metallic or of a material that may detach from the blades at the point where the structure extends outside the rudder blade, a suitable seal is to be provided to avoid ingress of water.

2.34.5 Rudders are to be filled with a suitable material upon completion of the join up, details of the filler material are to be submitted.

2.34.6 The diameter of the top of the rudder mainpiece must not be less than that of the rudder stock. For spade rudders this diameter may be gradually reduced for the lower third to not less than 75 per cent of the rudder stock diameter.

2.34.7 The rudder arms are to be efficiently attached to the mainpiece.

2.34.8 The laminate weight of moulded fibre reinforced plastics double plate rudders is to be determined by direct calculation, subject to a minimum laminate thickness of 5 mm.

2.35 Rudder tube arrangements

2.35.1 The rudder tube construction may be of aluminium alloy, steel, bronze or fibre reinforced plastic.

2.35.2 The scantlings of rudder tubes will be individually considered.

2.35.3 For steel and aluminium hulls, the bottom shell in way of the rudder tubes is to be additionally reinforced by means of an insert plate to increase the bottom shell thickness by 50 per cent.

2.35.4 For F.R.P hulls, the bottom shell laminate in way of the rudder tubes is to be locally increased by 50 per cent. The increased thickness in way of the rudder tube need not exceed the rule keel thickness requirement.

2.35.5 For F.R.P sandwich hulls the shell in way of the rudder tube connection is to be either:

(a) Reduced from the sandwich hull construction to single skin laminate for a distance of a least three times the rudder tube diameter about the rudder stock axis. The single skin region is to be additionally reinforced by a minimum of 50 per cent of the sum of the inner and outer sandwich laminate subject to this being at least equivalent to a 50 per cent increase in thickness of the Rule minimum bottom shell laminate for a single skin F.R.P. craft of the equivalent Rule length L_R. The reinforced laminate need not be greater than the Rule keel laminate thickness.
(b) Reduced from the sandwich hull construction to a single skin laminate for a distance of three times the rudder tube diameter about the rudder stock axis. After bonding in the rudder tube to the single skin laminate the foam core and inner skin are then reinstated.
(c) Proposals to replace the sandwich core with a core having higher core shear strength and compressive strength than that of the adjacent structure prior to bonding the tube to the inner and outer skins will be the subject of special consideration.

2.35.6 The rudder tube may be connected to the shell by bonding, bolting or welding as applicable depending upon the construction material of the shell.

2.35.7 When bonding in rudder tubes the bonding angle is to be not less than the Rule minimum bottom shell weight. F.R.P. tubes are to be thoroughly abraded and degreased prior to installation and laminating. Bonded in metallic tubes are to be knurled in way of the bonding material and thoroughly degreased prior to installation.

2.35.8 Where rudder tubes are to be retained by bolting they are to be provided with a substantial flange securely attached to the hull structure. Where bolts are used, the nuts are to be suitably locked.

2.35.9 Where rudder tubes are to be welded to hull insert plates full penetration welding is required.

2.35.10 Rudder tubes are to be supported by suitable brackets and deep floors to avoid hard spots on the shell and to ensure continuity of the main hull structure.

2.35.11 Rudder bearings are to be secured against rotation within the rudder tubes by suitable pinch bolting or keys. Details are to be submitted for approval.

2.36 Watertight arrangement

2.36.1 In rudder trunks which are open to the sea, a seal is to be fitted above the deepest load waterline, to prevent water from entering the steering gear compartment and the lubricant from being washed away from the rudder carrier. If the top of the rudder trunk is below the deepest waterline two separate seals are to be provided. Rudder trunk boundaries, where exposed to the sea, are to have a corrosion protection coating applied in accordance with the manufacturer's instructions.

2.36.2 Lip seals or 'O' rings may be used either in isolation or in combination with one or other of the seal arrangements.

2.36.3 A watertight gland body may be used. It is then to be formed by the top of the fabricated or cast rudder tube, the gland packing being retained against the top bearing or a check in the wall of the rudder tube and is compressed by a gland packet which may be of the flange type, screwed cap or other suitable arrangement.

2.37 In-water Survey requirements

2.37.1 Where an ***IWS** (In-water Survey) notation is to be assigned, *see Pt 1, Ch 2, 3.8 Other hull notations*, means are to be provided for ascertaining the rudder pintle and bush clearances and for verifying the security of the pintles in their sockets with the craft afloat.

■ *Section 3* Sternframes and appendages

3.1 General

3.1.1 Sternframes, rudder horns and boss end brackets may be constructed of cast or forged steel, cast or forged aluminium alloy, fabricated from aluminium or steel plate or moulded from fibre reinforced plastic dependent upon the material of construction of the craft. Where shaft brackets are fitted these may be either fabricated, cast or forged from steel or aluminium alloy as applicable to the material of construction of the main hull.

3.1.2 In castings, sudden changes of section or possible constrictions to the flow of metal during casting are to be avoided. All fillets are to have adequate radii, which, in general, are to be not less than 50 to 75 mm, depending on the size of the casting.

3.1.3 Castings and forgings are to comply with the requirements of *Ch 4 Steel Castings* and *Ch 5 Steel Forgings* of the Rules for Materials.

3.1.4 Sternframes, rudder horns, shaft brackets, etc. are to be effectively integrated into the craft structure, and their design is to be such as to facilitate this.

3.2 Sternframes

3.2.1 The scantlings of sternframes are to be determined from *Table 3.3.1 Sternframes*. In the case of very large craft, the scantlings and arrangements may be required to be verified by direct calculations.

Table 3.3.1 Sternframes

Item	Parameter	Requirement		
(1) Propeller posts		Cast steel (*see Figure 3.3.1 Propeller posts*)	Forged steel (*see Figure 3.3.1 Propeller posts*)	Fabricated mild steel (*see Figure 3.3.1 Propeller posts*)
	l	$165\sqrt{T}$	-	$200\sqrt{T}$ mm
	r	$20\sqrt{T}$	-	$18\sqrt{T}$ mm
	t_w	$8\sqrt{T}$ (need not exceed 38 mm) (*see* Notes 1 and 2)	-	$6\sqrt{T}$ mm (need not exceed 30 mm) (*see* Notes 1 and 2)
	t_1	$12\sqrt{T}$ (min 19 mm)	-	$12\sqrt{T}$ mm
	t_2	$16\sqrt{T}$ (min 25 mm)	-	-
	W	$115\sqrt{T}$ mm	$40\sqrt{T}$ mm	$140\sqrt{T}$ mm
	A	-	$(10 + 0{,}5L_R)T$ cm^2 where $L_R \leq 60$ m $40T$ cm^2 where $L_R \leq 60$ m	-
(2) Propeller boss (see Note 3 and *Figure 3.3.2 Propeller boss*)	t_b	$\left(0.1\delta_{TS} + 56\right)$ mm, but need not exceed $0.3\delta_{TS}$		

(3) Rudder posts or axles		Single screw with integral solepiece, *see Figure 3.3.5 Solepiece*	Single screw with bolted rudder axle, *see Figure 3.3.3 Rudder axle*	Twin screw, integral with hull, *see Figure 3.3.4 Rudder post for twin screw craft*
	n	-	6 (*see* Note 4)	-
	r	-	-	$20\sqrt{T}$ mm
	r_b	-	$\delta_A$mm	-
	t_F	-	$\delta_b$mm	-
	t_1	-	-	$12\sqrt{T}$ mm
	t_2	-	-	$15\sqrt{T}$ mm
	t_3	-	-	$18\sqrt{T}$ mm
	w	-	-	$120\sqrt{T}$ mm
	z_{PB1}, z_{PB2}	-	$1.2\delta_{PL2}$mm	-
	Z_T	$0.147 A_R b(V+3)^2 cm^3$	-	-
	δ_A	-	$25T + 76$mm but need not exceeded $0.9\delta_{PL2}$mm	-
	δ_b	-	$6.25T + 19$mm or $0.225\delta_{PL2}$mm whichever is the greater	-
	δ_{PL1}, δ_{PL2} bearing pressure and pintle clerance	-	As for rudder pintles (*see Table 3.2.10 Pintle requirements*)	-
4) Solepieces (see Notes 5,6 and 7)		With integral rudder post, *see Figure 3.3.5 Solepiece*	With bolted axle, *see Figure 3.3.5 Solepiece*	Open type (no rudder post), *see Figure 3.3.5 Solepiece*
(a) Cast Steel	Z_T	0,50W cm^3	0,95W cm^3	1,00W cm^3
	Z_V	0,35W cm^3	0,40W cm^3	0,50W cm^3
(b) Fabricated mild steel	Z_T	0,42W cm^3	0,81W cm^3	0,85W cm^3
Symbols				

L_R, T as defined in *Pt 3, Ch 1, 6.2 Principal particulars*

a,b,c = distances, in metres, as shown in *Figure 3.3.5 Solepiece*

n = number of bolts in palm coupling

r_b = mean distance of bolt centres from centre of palm, in mm

t_b = finished thickness of boss, in mm

x = distance, in metres, from centre of rudder stock to section under consideration

A = cross-sectional area of forged steel propeller post, in cm^2	
A_R = total rudder area, in m^2	
L_1 = L_R, but is to be taken not less than 90 m	
V = maximum service speed, in knots, with the craft in the loaded condition	
W = $\dfrac{400 A_R C (V+3)^2 (3 \times + a)}{b(L_1 + 640)}$	
Z_T = section modulus against transverse bending, in cm^3	
Z_V = section modulus against vertical bending, in cm^3	
δ_b = diameter of coupling bolts, in mm	
δ_{TS} = diameter of tail shaft, in mm	

Note 1. Where scantlings and proportions of the propeller post differ from those shown in Item 1, the section modulus about the longitudinal axis of the proposed section normal to the post is to be equivalent to that with Rule scantlings. t_1 is to be not less than 8 $\sqrt{T}$ (minimum of 19mm for cast steel sternframes)

Note 2. On sternframes without solepieces, the modulus of the post below the propeller boss, about the longitudinal axis may be gradually reduced to not less than 85% of that required by Note 1, subject to the same thickness limitations.

Note 3. In fabricated sternframes the connection of the propeller post to the boss is to be by full penetration welds.

Note 4. If more than six bolts are fitted, the arrangements are to provide equivalent strength.

Note 5. In fabricated solepieces, transverse webs are to be fitted spaced not more than 760 mm apart. Where the breadth of the solepiece exceeds 900 mm, a centreline vertical web is also to be fitted.

Note 6. Solepieces supporting fixed or movable nozzles will be specially considered (*see Pt 3, Ch 13, 3 Fixed and steering nozzles* of the *Rules and Regulations for the Classification of Ships, July 2021*).

Note 7. For dredging and reclamation craft in restricted service Groups G1, G2 or G3, the scantlings of an `open' type solepiece are to be such that:

(a) Z_T = 0,625W cm^3

(b) The cross-sectional area is not less than 18 cm^2.

(c) The depth is not less than two-thirds of the width at any point.

3.2.2 Fabricated and cast propeller posts and rudder posts of twin screw craft are to be strengthened at intervals by webs. In way of the upper part of the sternframe arch, these webs are to line up with the floors.

3.2.3 Rudder posts and propeller posts are to be connected to floors of increased thickness. *See Pt 6, Ch 3, 5 Single bottom structure and appendages* and *Pt 7, Ch 3, 5 Single bottom structure and appendages* for steel and aluminium alloy construction respectively.

3.2.4 The requirements for sternframes of composite craft are to be in accordance with *Pt 8, Ch 3, 5.9 Sternframes*.

3.3 Rudder horns

3.3.1 The requirements for the scantlings and arrangements of rudder horns are given in *Pt 6, Ch 3, 5.9 Rudder horns* and *Pt 7, Ch 3, 5.9 Rudder horns* for steel and aluminium alloy construction and *Pt 8, Ch 3, 5.8 Rudder horns* for composite construction respectively.

3.4 Shaft bossing

3.4.1 Where the propeller shafting is enclosed in bossings extending back to the bearings supporting the propellers, the aft end of the bossings and the bearings are to be supported by substantially constructed boss end castings or fabrications. These are to be designed to transmit the loading from the shafting efficiently into the craft's internal structure.

3.4.2 For shaft bossings attached to shaft brackets, the length of the boss is to be adequate to accommodate the aftermost bearing and to allow for proper connection of the shaft brackets.

3.4.3 Cast steel supports are to be suitably radiused where they enter the main hull to line up with the boss plating radius. Where the hull sections are narrow, the two arms are generally to be connected to each other within the craft. The arms are to be strengthened at intervals by webs.

3.4.4 Fabricated supports are to be carefully designed to avoid or reduce the effect of hard spots. Continuity of the arms into the craft is to be maintained, and they are to be attached to substantial floor plates or other structure. The connection of the arms to the bearing boss is to be by full penetration welding.

3.4.5 The scantlings of supports will be specially considered. In the case of certain high powered craft, direct calculations may be required.

3.4.6 The boss plating is generally to be radiused into the shell plating and supported at the aft end by diaphragms at every frame. These diaphragms are to be suitably stiffened and connected to floors or a suitable arrangement of main and deep web frames. At the forward end, the main frames may be shaped to fit the bossing, but deep webs are generally to be fitted not more than four frame spaces apart.

3.5 Shaft brackets

3.5.1 The scantlings of the arms of shaft brackets, based on a breadth to thickness ratio of about five, are to be determined from *Pt 3, Ch 3, 3.6 Single arm shaft brackets ('P' - brackets) 3.6.1* and *Pt 3, Ch 3, 3.7 Double arm shaft brackets ('A' - brackets) 3.7.2*.

3.5.2 Where the propeller shafting is exposed to the sea for some distance clear of the main hull, it is generally to be supported adjacent to the propeller by independent brackets having two arms. In very small craft the use of single arm brackets will be considered.

3.5.3 Fabricated brackets are to be designed to avoid or reduce the effect of hard spots and ensure a satisfactory connection to the hull structure. The connection of the arms to the bearing boss is to be by full penetration welding.

3.5.4 Where bracket arms are carried through the shell plating, they are to be attached to floors or girders of increased thickness. The shell plating is to be increased in thickness and connected to the arms by full penetration welding.

3.5.5 In the case of certain high powered craft direct calculations may be required.

3.5.6 For shaft brackets having hollow section arms, the cross-sectional areas at the root and the boss should not be less than that required for a sold arm which satisfies the Rule section modulus having the proportions stated in *Pt 3, Ch 3, 3.5 Shaft brackets 3.5.1*. Hollow sections are to have a continuous central main piece connecting the shells at or near the location of greatest width, alternative arrangements will be specially considered.

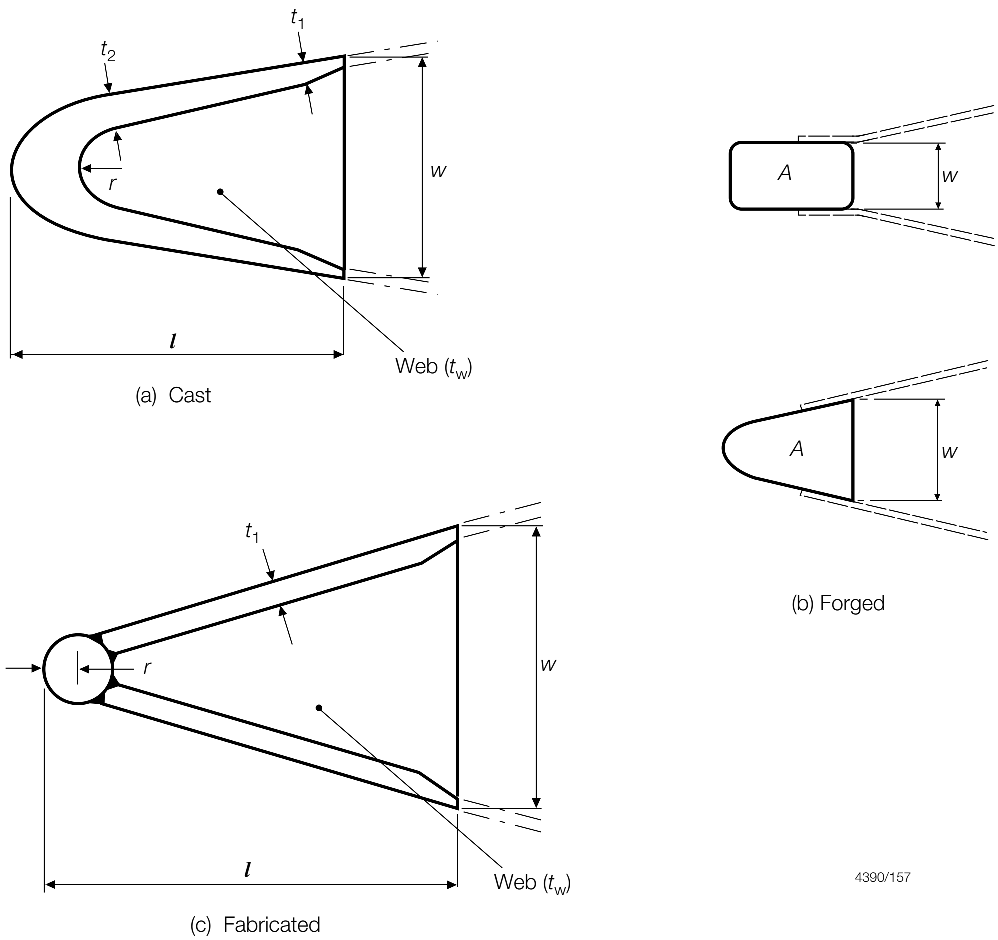


Figure 3.3.1 Propeller posts

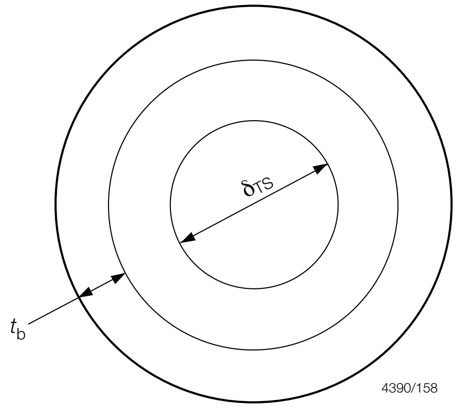


Figure 3.3.2 Propeller boss

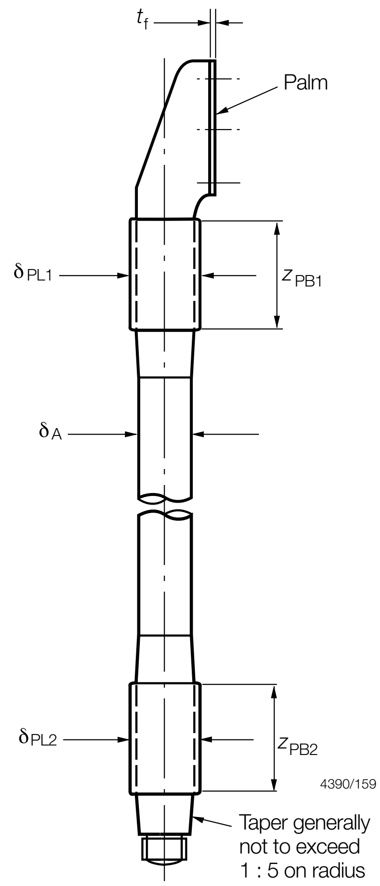


Figure 3.3.3 Rudder axle

3.5.7 The length of the shaft bracket boss, l_b , is to be sufficient to support the length of the required bearing. In general l_b is not to be less than 4d_t , where d_t is the Rule diameter of the screwshaft, in mm, *see Pt 11, Ch 2, 4.4 Screwshafts and tube shafts*. Proposals for a reduction in the required shaft bracket boss length will be considered in conjunction with details of the bearing material, allowable bearing operating pressure and installation arrangements, *see Pt 11, Ch 2, 4.16 Sternbushes and sterntube arrangements 4.16.2*. However in no case is l_b to be less than the greater of:

(a) 2d_t ; or
(b) that recommended by the bearing manufacturer; or
(c) as required by *Pt 3, Ch 3, 3.4 Shaft bossing 3.4.2*.

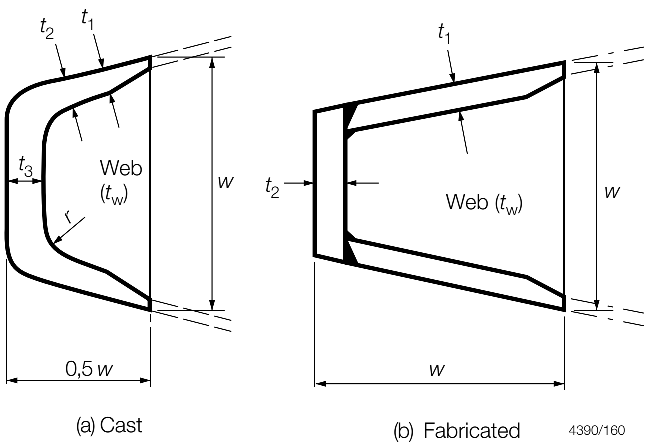


Figure 3.3.4 Rudder post for twin screw craft

3.5.8 Where the shaft and the shaft bracket boss are of the same material, the thickness of the shaft bracket boss is not to be less than d_t /4. Where the shaft and the shaft bracket boss are of dissimilar materials, the thickness of the boss, t_b , is to be not less than:

$$t_b = 0,75 d_t \left(\sqrt[3]{f_1} - 0,667 \right) \text{mm}$$

Note In no case is t_b to be taken as less than 12 mm.

where

d_t = Rule diameter of the screwshaft, in the appropriate screwshaft material, in mm, *see Pt 11, Ch 2, 4 Design and construction*

f_1 = σ_S/σ_B but not less than 0,825

σ_S = ultimate tensile strength of the shaft material, in N/mm^2

σ_B = ultimate tensile strength of the boss material, in N/mm^2.

3.5.9 The design of the shaft brackets with regard to hydrodynamic effects causing vibrational excitations as well as disturbance of the hydrodynamic flow into the propeller and rudders is outside the scope of classification. However, it is recommended that the effects of periodic excitation caused by vortex shedding or other sources be carefully examined in order to prevent excessive structural vibration. The responsibility for such investigation rests with the designer.

3.6 Single arm shaft brackets ('P' - brackets)

3.6.1 Single arm shaft brackets are to have a section modulus, Z_{xx}, at the palm of not less than that determined from the formula:

$$Z_{xx} = \frac{a_s d_{up}^2 f}{45000} \text{cm}^3$$

where

a_s = the length of the arm to be measured from the centre of the section at the palm to the centreline of the shaft boss, in mm, *see Figure 3.3.6 Single arm shaft bracket*

d_{up} = the Rule diameter for an unprotected screwshaft, in mm, as given in *Pt 11, Ch 2, 4 Design and construction*, using A = 1,0

where

f = $400/\sigma_u$

σ_u = ultimate tensile strength of arm material, in N/mm^2

The cross-sectional area of the bracket at the boss is to be not less than 60 per cent of the area of the bracket at the palm.

3.6.2 For single arm shaft brackets a vibration analysis may be required if deemed necessary by LR.

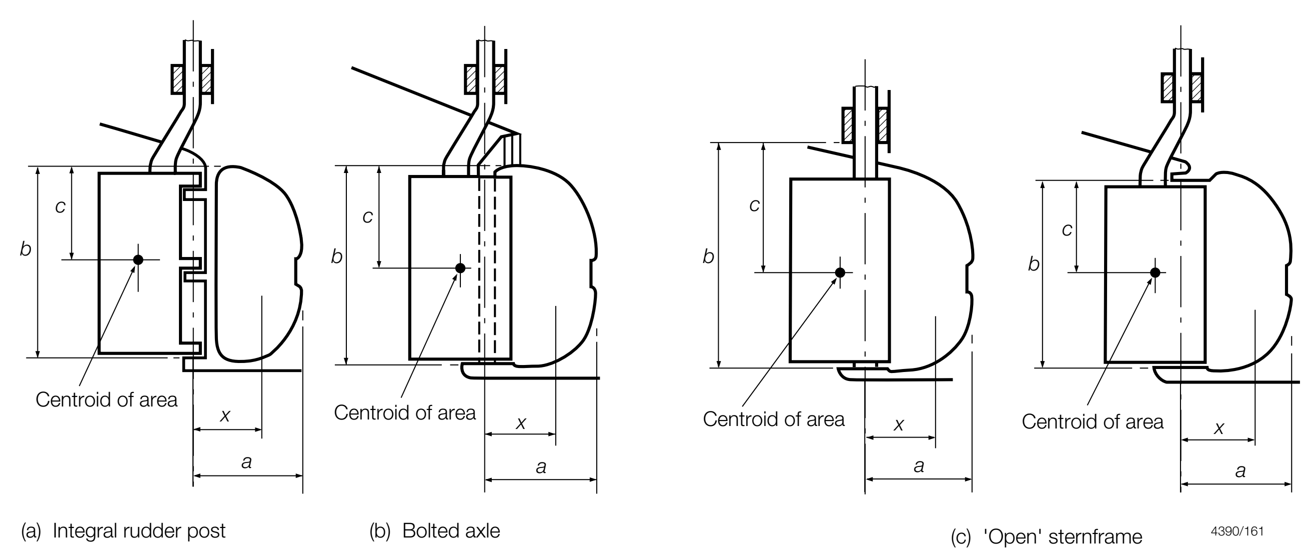


Figure 3.3.5 Solepiece

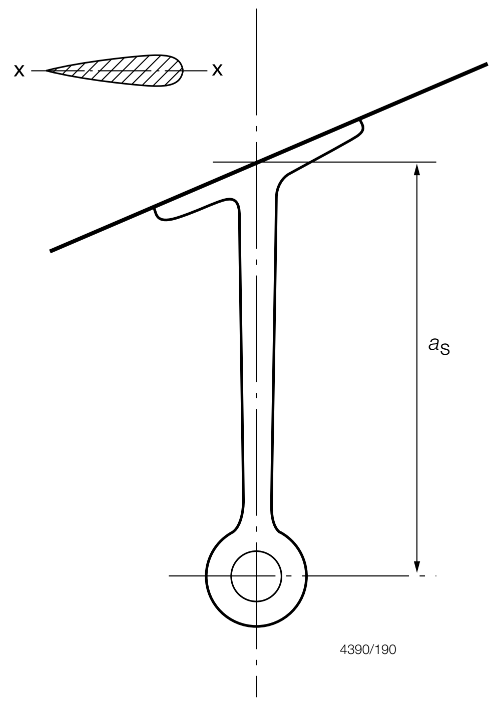


Figure 3.3.6 Single arm shaft bracket

3.7 Double arm shaft brackets ('A' - brackets)

3.7.1 The angle between the arms for double arm shaft brackets is to be generally not less than 50°. Proposals for the angle between the arms to be less than 50° will be specially considered with supporting calculations to be submitted by the designers.

3.7.2 The arms of double arm shaft brackets are to have a section modulus, Z_{xx}, of not less than that determined from the formula:

$$Z_{xx} = 0,45 n^3 \, cm^3$$

where

n = the minimum thickness, in cm, of a hydrofoil section obtained from:

= $$n = d_{up} \sqrt{\left(\frac{f}{2000}\right)\left(1 + \sqrt{\left(1 + \left(\frac{0,0112}{f}\right)\left(\frac{a_d}{d_{up}}\right)^2\right)}\right)} \text{cm}$$

a_d = the length of the longer strut, in mm, *see Figure 3.3.7 Double arm shaft bracket*

d_{up} and f are as given in *Pt 3, Ch 3, 3.6 Single arm shaft brackets ('P' - brackets) 3.6.1*.

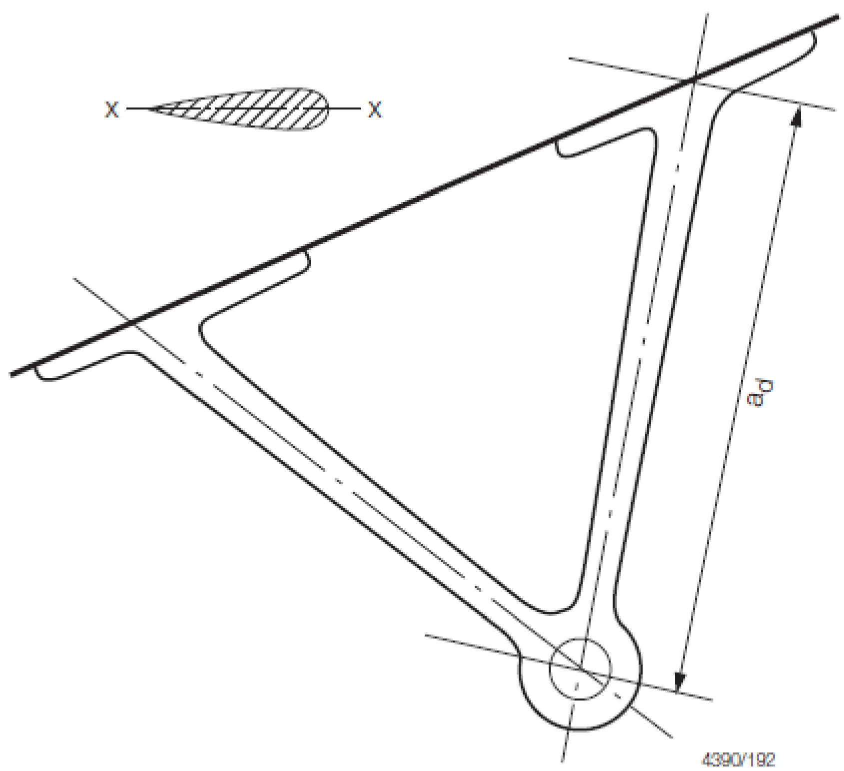


Figure 3.3.7 Double arm shaft bracket

3.8 Intermediate shaft brackets

3.8.1 The length and thickness of the shaft bracket boss are to be as required by *Pt 3, Ch 3, 3.5 Shaft brackets 3.5.7* or *Pt 3, Ch 3, 3.5 Shaft brackets 3.5.8* as appropriate. The scantlings of the arms will be specially considered on the basis of the Rules.

3.9 Attachment of shaft brackets by welding

3.9.1 Fabricated supports are to be carefully designed to avoid or reduce the effect of hard spots. Continuity of the arms into the craft is to be maintained, and they are to be attached to substantial floor plates or other structure. The connection of the arms to the bearing boss is to be by full penetration welding.

3.10 Attachment of shaft brackets by bolting

3.10.1 The bottom shell thickness in way of the double arm propeller bracket palms is to be increased by 50 per cent. The bottom shell thickness in way of single arm propeller brackets palms is to be doubled in thickness. The insert plates, or reinforced shell laminate in FRP craft, are to be additionally supported by substantial floor plates or other structure.

3.10.2 Where shaft brackets are attached by bolts, they are to be provided with substantial palms securely attached to the hull structure which is to be adequately stiffened in way. Where bolts are used, the nuts are to be suitably locked.

3.10.3 The bracket palms may be bolted directly onto the shell using a suitable bedding compound. The palms may be bolted onto suitable shims or chocking compound, of an approved type, to facilitate alignment.

3.10.4 Where brackets are bolted onto resin chocks, plans indicating the following information are to be submitted for approval:

(a) The thrust and torque loads, where applicable, that will be applied to the chocked item.
(b) The torque load to be applied to the bracket mounting bolts.
(c) The material of the bracket mounting bolts.
(d) The number, thread size, shank diameter and length of the mounting bolts.

3.10.5 The minimum thickness of a resin chock is to be 12 mm.

3.10.6 The bracket palms are to have well radiused corners, and the faying surface to be dressed smooth. The palm thickness in way of the bolts is to be not less than the propeller bracket boss thickness from *Pt 3, Ch 3, 3.5 Shaft brackets 3.5.7* or *Pt 3, Ch 3, 3.5 Shaft brackets 3.5.8* as appropriate.

3.10.7 The diameter of the propeller bracket mounting bolts is to be not less than:

$$d_{\mathrm{b}} = \sqrt{\frac{Z_{xx}}{8,75\,\pi\,nh \times 10^{-5}}}\ \mathrm{mm}$$

and not less than the shell plate thickness in way of the palm or 12 mm, whichever is greater

where

Z_{xx} = the section modulus of the bracket arm determined from *Pt 3, Ch 3, 3.6 Single arm shaft brackets ('P' - brackets) 3.6.1* or *Pt 3, Ch 3, 3.7 Double arm shaft brackets ('A' - brackets) 3.7.2*, in cm^3, as appropriate

n = the number of bolts in each row

h = the distance between rows of bolts, in mm

d_{b} = the bolt diameter in the same material as the propeller bracket, in mm.

3.10.8 Where the shaft bracket and the shaft bracket mounting bolts are of dissimilar materials (which are galvanically compatible), the diameter of the propeller bracket mounting bolts, as determined from *Pt 3, Ch 3, 3.10 Attachment of shaft brackets by bolting 3.10.7*, is to be modified in proportion to the square root of the yield strengths of the particular materials. The corrected bolt diameter of the dissimilar material is to be not less than the propeller bracket boss thickness.

3.10.9 The propeller bracket palms are to have fitted bolts, and suitable arrangements provided to lock the nuts.

3.10.10 A washer plate is to be provided, generally of equal dimensions to the bracket palm with thickness t_{b}/6 mm, subject to a minimum of 3 mm.

3.11 Attachment of shaft brackets by bonding

3.11.1 Proposals to connect shaft brackets to FRP hulls by bonding will be the subject of special consideration. Details of the following are to be submitted:

(a) Preparation of the hull penetration and internal bonding surface.
(b) Details of transverse through pinning of the shaft bracket strut.

(c) Details of over bonding of strut and pin arrangement and subsequent integration of strut into primary hull structure.

3.12 Alignment of shaft brackets

3.12.1 Particular care is to be paid to the alignment of shaft brackets to minimise vibration and cyclic loadings being transmitted from the propulsion shafting and propellers into the hull structure.

3.12.2 Alignment of bolted shaft brackets may be by means of suitable metallic shims or chocking resin of an approved type. *See Pt 3, Ch 3, 3.10 Attachment of shaft brackets by bolting 3.10.2* and *Pt 3, Ch 3, 3.10 Attachment of shaft brackets by bolting 3.10.3*.

3.12.3 The alignment of shaft brackets connected by welding or bonding may be facilitated by boring of the bracket boss after attachment of the shaft bracket and sterntube.

3.13 Sterntubes

3.13.1 The sterntube construction may be of aluminium alloy, steel, bronze or fibre reinforced plastic.

3.13.2 The sterntube scantlings are to be individually considered.

3.13.3 For steel and aluminium hulls, the bottom shell, in way of the sterntube, is to be additionally reinforced by means of an insert plate to increase the bottom shell thickness by 50 per cent.

3.13.4 For FRP hulls, the bottom shell laminate, in way of the sterntube, is to be locally increased by 50 per cent by gradual tapering of the laminate. The increased thickness in way of the sterntube need not exceed the Rule keel thickness requirement.

3.13.5 For FRP sandwich hulls the shell in way of the stern tube connection is to be either:

(a) Reduced from sandwich hull construction to single skin laminate by removal of the core and by combining the inner and outer skins. The single skin region is then to be additionally reinforced by a minimum of 50 per cent of the sum of the inner and outer sandwich laminate. The increased thickness in way of the sterntube need not be greater than the Rule keel thickness requirement.
(b) Reduced from the sandwich hull construction to a single skin laminate by removal of the core and combining the inner and outer skins. After bonding in the sterntube to the single skin laminate the foam core and the inner skin are to be reinstated.
(c) Proposals to replace the sandwich core with a core having higher core shear strength and compressive strength than that of the adjacent structure prior to bonding the tube to the inner and outer skins will be the subject of special consideration.

3.13.6 The sterntube may be connected to the shell by bonding, bolting or welding as applicable depending upon the construction material of the shell.

3.13.7 When bonding in sterntubes the bonding angle laminate weight is to be not less than the Rule minimum bottom weight. FRP tubes are to be thoroughly abraded and degreased prior to installation and laminating. Bonded in metallic tubes are to be knurled in way of the bonding material and thoroughly degreased prior to installation. During the bonding operation particular care is to be given to maintaining the sterntube alignment.

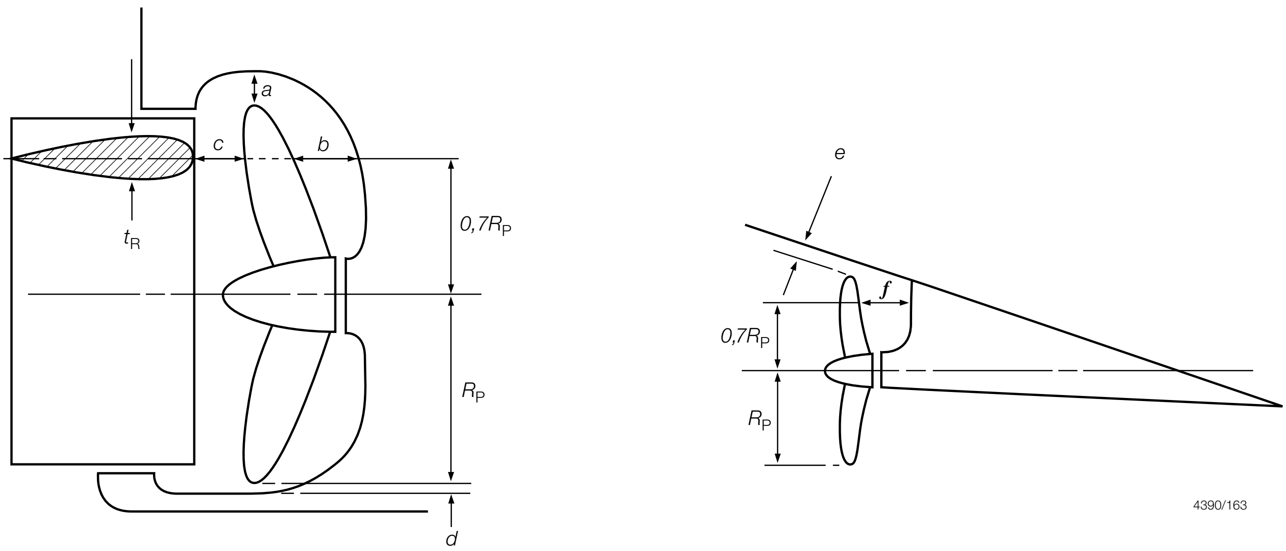
3.13.8 Where sterntubes are to be retained by bolting, they are to be provided with a substantial flange securely attached to the hull structure. Where bolts are used, the nuts are to be suitably locked.

3.13.9 Where sterntubes are to be welded to hull insert plates full penetration welding is required.

3.13.10 Where sterntubes are to be installed using a resin system, of an approved type, the requirements of *Pt 11, Ch 2, 4.16 Sternbushes and sterntube arrangements* are to be complied with.

3.13.11 The region where the shafting enters the craft, and the bearing in way, are to be adequately supported by floors or deep webs.

3.13.12 The shaft bearings are to be secured against rotation within the sterntube.



(a) Single screw (b) Twin screw

Figure 3.3.8 Propeller clearance

3.13.13 A suitable gland arrangement is to be provided at the inboard end of sterntubes in accordance with *Pt 11, Ch 2, 4.15 Intermediate bearings*.

3.13.14 Where difficulty in welding or bonding of sterntube to the hull is anticipated due to small clearances or tight angles, a local cofferdam or watertight compartment of moderate volume is to be fitted enclosing the hull penetration and the sterntube. Where the sterntube penetrates the inboard boundary of the watertight compartment or cofferdam, it is to be suitably supported and sealed.

3.14 Solepieces

3.14.1 The requirements for solepieces are as indicated in *Table 3.3.1 Sternframes*.

3.15 Propeller hull clearances

3.15.1 Recommended minimum clearances between the propeller and the sternframe, rudder or hull are given in *Table 3.3.2 Recommended propeller hull clearances*. These are the minimum distances considered desirable in order to expect reasonable levels of propeller excited vibration. Attention is drawn to the importance of the local hull form characteristics, shaft power, water flow characteristics into the propeller disc and cavitation when considering the recommended clearances.

Table 3.3.2 Recommended propeller hull clearances

Number of Blades	Hull clearances for single screw, in metres, *see Figure 3.3.8 Propeller clearance*				Hull clearances for twin screw in metres, *see Figure 3.3.8 Propeller clearance*	
	a	b	c	d	e	f
3	1,20$K\delta$	1,80$K\delta$	0,12δ	0,03δ	1,20$K\delta$	1,20$K\delta$
4	1,00$K\delta$	1,50$K\delta$	1,12δ	0,03δ	1,00$K\delta$	1,20$K\delta$
5	0,85$K\delta$	1,275$K\delta$	0,12δ	0,03δ	0,85$K\delta$	0,85$K\delta$
6	0,75$K\delta$	1,125$K\delta$	0,12δ	0,03δ	0,75$K\delta$	0,75$K\delta$
Minimum value	0,10δ	0,15δ	t_R	-	3 and 4 blades	0,15δ

					0,20δ 5 and 6 blades 0,16δ	
Symbols						
L_R and C_b as defined in *Pt 3, Ch 1, 6.1 General* $K = \left(0,1 + \frac{L_R}{3050}\right)\left(\frac{3,48 C_b P_s}{L_R^2} + 0,3\right)$				t_R = thickness of rudder, in metres measured at $0,7R_p$ above the shaft centreline P_s = designed power on one shaft, in kW R_p = propeller radius, in metres δ = propeller diameter, in metres		
Note The above recommended minimum clearances also apply to semi-spade type rudders.						

■ *Section 4*
Fixed and steering nozzles, bow and stern thrust units

4.1 General

4.1.1 Fixed and steering nozzles are, in general, to be in accordance with *Pt 3, Ch 13, 3 Fixed and steering nozzles* of the *Rules and Regulations for the Classification of Ships, July 2021*.

4.2 Steering gear and allied systems

4.2.1 For the requirements of steering gear, *see Pt 12, Ch 1 Propellers*.

4.3 Thruster unit wall thickness

4.3.1 The wall thickness of the unit is, in general, to be in accordance with the manufacturer's practice, but is to be not less than:

(a) For steel hulls, the thickness of the adjacent shell plating plus 10 per cent or 2 mm whichever is the greater, subject to a minimum of 7 mm.
(b) For aluminium hulls, the thickness of the adjacent shell plating plus 10 per cent or 1 mm whichever is the greater, subject to a minimum of 8 mm.
(c) For FRP hulls, generally the thickness of the adjacent shell laminate plus 25 per cent subject to a minimum of 8 mm. Full details of the proposed laminate and resin system are to be submitted for approval.

4.4 Thruster unit installation details

4.4.1 The method of attachment of the tube is dependent upon the tube and the craft's construction materials which may be steel, aluminium alloy or FRP.

4.4.2 The tunnel tube is to be fitted either between a pair of deep floors or bulkheads extending to above the design waterline or in a separate watertight compartment.

4.4.3 The shell plating thickness is to be locally increased by 50 per cent in way of tunnel thruster connections.

4.4.4 For welded tube connections the welding is to be by full penetration welding.

4.4.5 For FRP tubes attached by bonding the total bonding reinforcement weight is to be at least that of the hull bottom laminate with the tube bonded internally and externally to the shell laminate. Prior to bonding *in situ* the areas to be bonded are to be thoroughly abraded and degreased and all cut FRP laminate edges resin sealed.

4.4.6 The tunnel tube is to be framed to the same standard as the surrounding shell plating.

4.4.7 The unit is to be adequately supported and stiffened.

4.5 Novel features

4.5.1 Where the Rules do not specifically define the requirements for novel features then the scantlings and arrangements are to be determined by direct calculations. Such calculations are be carried out on the basis of the Rules, recognised standards and good practice, and are to be submitted for consideration.

■ *Section 5*
Stabiliser arrangements

5.1 General

5.1.1 The scantlings, arrangements and effectiveness of the stabilizers are outwith the scope of classification; however their foundations, supporting structure and watertight integrity are to be examined.

5.2 Fin stabilisers

5.2.1 Detailed plans are to be submitted clearly indicating the position, supporting structure and design loads for all fins.

5.2.2 The design, construction, operational performance and control systems of the fin stabiliser unit are outside the scope of classification.

5.2.3 Fin stabilisers are to be contained within a watertight enclosure. The purpose of the watertight enclosure is to ensure that any impact to the stabiliser will not affect the survivability or safe operation of the craft. In addition to the requirements of *Pt 3, Ch 3, 5.2 Fin stabilisers 5.2.4*, when determining the location and extent of the watertight enclosure the following should be considered:

(a) Stabiliser blade construction material.
(b) Designed failure mode of stabiliser shaft.
(c) Damage stability requirements of craft.
(d) Survivability of craft after impact to the stabiliser.
(e) Function of space containing stabiliser.

5.2.4 For non-retractable type stabilisers, the watertight divisions forming the forward and aft boundaries of the watertight enclosure are to be arranged not less than one third of the root chord length, C, from the fore and aft extents of the stabiliser, *see Figure 3.5.1 Stabiliser positioning*. Main watertight subdivision bulkheads may be considered as watertight divisions where appropriate.

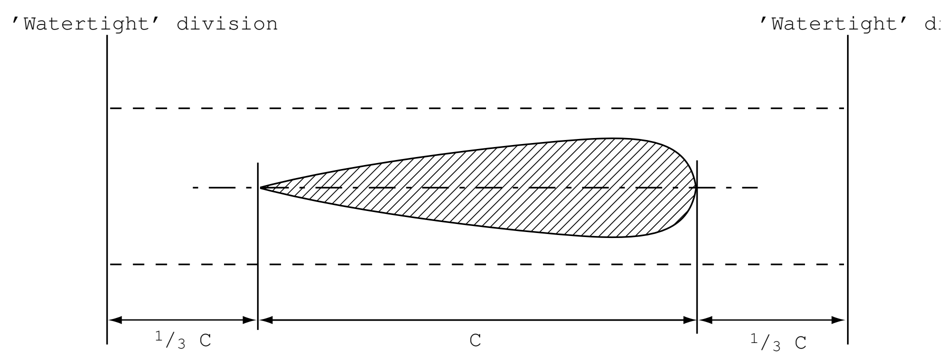


Figure 3.5.1 Stabiliser positioning

5.2.5 For craft constructed of mild steel the watertight enclosure into which the stabilisers retract is to have a perimeter plating of the same thickness as the surrounding Rule shell plating plus 2 mm, and is to be stiffened to the same standard as the shell. For craft constructed from aluminium alloys the corrections in *Pt 3, Ch 3, 1.2 General 1.2.2* apply.

5.2.6 For craft constructed from composite materials the laminate thickness of the watertight enclosure into which the stabilisers retract is to be specially considered. Generally the thickness should not be less than that of the bottom shell.

5.2.7 Insert plates are to be fitted or laminate thickness increased in way of stabilisers. The thickness of the insert plate or increased laminate is to be at least 50 per cent greater than the bottom shell thickness in way, and is to extend over an area formed by 1,25 times the stabiliser root chord length and covering all operational angles. In addition, for retractable stabilisers the insert is to extend beyond the shell opening for a distance of not less than 25 per cent the length of the root chord.

5.2.8 Fin stabiliser systems are, in general, not to extend beyond the extreme moulded beam of the hull or below the horizontal line of keel. However, for retractable fins, alternative arrangements may be specially considered. Where the stabiliser fin extends beyond the extreme moulded beam of the hull in the active mode, the side shell is to be permanently marked indicating the forward and aft extent of the stabiliser when deployed. It is recommended that an appropriate symbol be placed on the hull side between the marks.

5.2.9 The stabiliser machinery and surrounding structure is to be adequately supported and stiffened. Where bending stresses are induced in the structure under fatigue conditions the maximum stress is not to exceed 39,0 N/mm^2 in mild steel. Where other materials are used for the supporting structure the limiting stress values will be specially considered on the basis of the Rules.

5.2.10 The scantlings of internal watertight bulkheads and stiffening for fixed installations are to be as specified by the designer/ Builder and/or fin unit manufacturer but in no case are to be less than the scantlings for double bottoms as defined in *Pt 6, Ch 3, 6 Double bottom structure* for steel structures *Pt 7, Ch 3, 6 Double bottom structure* for aluminium structures. Suitable access is to be provided to allow for maintenance and inspection purposes.

5.2.11 The scantlings and sealing arrangements for the pedestal and bearings will be specially considered, subject to the designer/Builder submitting the following:

(a) Detailed structural calculations for the proposed foundation and adjacent supporting structure.
(b) A detailed finite element model, if carried out, *see Pt 3, Ch 1, 2 Direct calculations*.
(c) Calculations demonstrating that the effect of damage to the stabiliser arrangement arising from high speed impact, grounding, fouling, etc. will not compromise the structural and watertight integrity of the craft.
(d) Maximum torque, bending moments and bearing loads expected for the proposed design.
(e) The stabiliser fin stock material, together with its ultimate tensile and shear strength values (N/mm^2).

5.2.12 Fin bearing materials and seals are to be of an approved type.

5.2.13 Where retractable stabilisers are fitted, position indicators are to be provided on the bridge and adjacent to the stabiliser installation.

5.3 Stabiliser tanks

5.3.1 The general structure of the tank is to comply with the Rule requirements for deep tanks. Sloshing forces in the tank structure are to be taken into account. Where such forces are likely to be significant, the scantlings will be required to be verified by additional calculations.

5.4 Ride control systems

5.4.1 The scantlings, arrangements and effectiveness of ride control systems are currently outwith the scope of classification; however their foundations, supporting structure and watertight integrity together with the associated reaction forces on the hull structure are to be examined. Details of the loadings and supporting calculations are to be submitted with the relevant construction plans for consideration.

5.5 Motion damping arrangements and devices

5.5.1 Motion damping devices are generally outwith the scope of the Rules. Where motion damping devices are fitted the designers/Builders are to submit details of the anticipated loadings and supporting calculations for appraisal of the adjacent hull structure.

5.6 Novel features

5.6.1 Where the Rules do not specifically define the requirements for novel features then the scantlings and arrangements are to be determined by direct calculations. Such calculations are to be carried out on the basis of the Rules, Recognised Standards and good practice, and are to be submitted for consideration.

■ *Section 6* Particular requirements for multi-hull craft

6.1 General

6.1.1 The requirements for control systems of multi-hull craft are generally in accordance with the requirements of *Pt 3, Ch 3, 1 General* for mono-hulls.

6.2 Rudders

6.2.1 The scantlings for rudders are to be generally in accordance with *Pt 3, Ch 3, 2 Rudders*. Where the proposed rudder is of a novel design or the speed of the craft exceeds 45 knots the scantlings of the rudder and rudder stock are to be determined from direct calculation methods incorporating model test results and structural analysis, as considered necessary by LR.

6.3 Sternframes and appendages

6.3.1 Sternframes and appendages are to be considered on the basis of the Rules. Reference is also to be made to *Pt 6, Ch 5 Special Features Pt 7, Ch 5 Special Features* and *Pt 8, Ch 5 Special Features* for steel, aluminium alloy and composite construction respectively.

6.4 Fixed and steering nozzles, bow and stern thrust units

6.4.1 In general, the requirements are to be in accordance with *Pt 3, Ch 3, 4 Fixed and steering nozzles, bow and stern thrust units*.

6.5 Stabiliser arrangements

6.5.1 In general, the requirements for multi-hulls are to be in accordance with the requirements of *Pt 6, Ch 3, 5 Single bottom structure and appendages*, and *Pt 6, Ch 5, 2.4 Surface drive mountings*, *Pt 7, Ch 5, 2.4 Surface drive mountings* and *Pt 8, Ch 5, 2.4 Surface drive mountings*, dependent upon the material of construction.

■ *Section 1*
General

1.1 Application

1.1.1 The contents of this Chapter are applicable to mono-hull and multi-hull craft constructed in steel, aluminium alloy or composite materials classed in service groups **G1** to **G6**.

1.1.2 The requirements in this Chapter are not applicable to craft classed in service groups **Zone 1** to **Zone 3**. Closing arrangements and outfit for craft classed in service groups **Zone 1** to **Zone 3** are to comply with the requirements of the National Authority. In the absence of National Authority requirements the relevant requirements of the *Rules and Regulations for the Classification of Inland Waterways Ships, July 2021* are to be complied with.

1.1.3 Where the requirements of *Pt 1, Ch 2, 1.1 General 1.1.11* require the craft to be subdivided for damage stability aspects these will be considered in addition to the requirements of this Part.

1.1.4 Attention is, however, to be given to any other additional statutory requirements of the National Authority in which the craft is registered.

1.2 Downflooding

1.2.1 Yachts and craft to which the *International Convention on Load Lines, 1966* is applicable, *see Pt 1, Ch 2, 1.1 General 1.1.11*, are to comply with the requirements of this sub-Section.

1.2.2 Doors, hatches, ventilators, windows, portlights, etc. provided with closing appliances which can be secured weathertight, and small openings through which progressive flooding cannot take place are not considered as down flooding points.

1.2.3 Air pipes are to be fitted with automatic closing appliances unless it can be shown that, with the craft at its summer load waterline, the openings will not be immersed at an angle of heel of 40°, or the angle of downflooding if this is less than 40°.

1.3 Definitions and symbols

1.3.1 The **down flooding angle** is the least angle of heel at which openings in the hull, superstructure or deckhouses, which cannot be closed weathertight, immerse and allow flooding to occur.

1.3.2 L_L is the loadline length as defined in *Pt 3, Ch 1, 6.2 Principal particulars 6.2.3*.

1.3.3 Position 1 and Position 2 are as defined in *Pt 3, Ch 1, 6.10 Position 1 and Position 2*.

1.4 Bolted connections

1.4.1 Bolted connections are generally to be in accordance with *Table 4.1.1 Bolt pitch requirements for structural connections*. Further requirements are contained throughout this Chapter.

Table 4.1.1 Bolt pitch requirements for structural connections

Location	Pitch
Manhole covers to fuel tanks	$6d_b$
Manhole covers to water tanks	$8d_b$
Covers over void tanks/ cofferdams	$10d_b$
Unstiffened portable plates in decks	$5d_b$
Bolted watertight door frames	$8d_b$
Window frames to superstructure	$20d_b$
Note d_b is the diameter of the bolt	

■ *Section 2* Bulkhead openings

2.1 General

2.1.1 In addition to the requirements of this Section, where compliance with *Pt 4, Ch 2, 1 General* and *Chapter X - Safety measures for high-speed craft* of *SOLAS 1974*, as amended (*High Speed Craft Code*), is required, the number and construction of the watertight doors in bulkheads will be considered in accordance with these requirements. Each watertight door is to be subjected to a pressure test, *see Table 1.7.1 Testing requirements* in Chapter 1. The test may be carried out either before or after the door is fitted. Regulations regarding openings in watertight bulkheads relevant to passenger or cargo craft, as appropriate, contained in the *International Convention for the Safety of Life at Sea, 1974* and applicable amendments, and *Pt 4, Ch 2, 1 General* are also to be complied with.

2.2 Openings in bulkheads below the freeboard deck

2.2.1 Certain openings below the freeboard deck are permitted, but these must be kept to a minimum and provided with means of closing to watertight standards. All such openings are to be to the satisfaction of the Surveyor.

2.3 Watertight doors

2.3.1 Watertight doors are to be efficiently constructed and fitted, and are to be capable of being operated when the craft is listed up to 15^{o} either way. They are to be operated under working conditions and hose tested in place. *See Pt 3, Ch 1, 7.3 Testing procedures*.

2.3.2 Where the doors are fitted in watertight bulkheads they are to be of equivalent strength to the unpierced bulkhead and capable of being closed watertight. Watertight doors are to be of a type, approved and pressure tested, *see Table 1.7.1 Testing*

requirements in Chapter 1, from both sides for the maximum head of water indicated by any required damage stability calculations or up to the bulkhead deck whichever is the greater.

2.3.3 Indicators are to be provided on the bridge showing whether the doors are open or closed.

2.3.4 Doors are to be capable of being operated from both sides of the bulkhead. Power operated sliding doors are to be capable of being opened and closed locally by both power and efficient hand operated mechanisms.

2.3.5 Doors not required to be used at sea may be of the hinged or sliding type. A notice is to be fixed on the closing appliance saying it should be kept closed at all times while the craft is at sea.

2.3.6 Watertight doors which are intended to be used while at sea are to be of the sliding type capable of being remotely closed from the bridge. An audible alarm is to be provided at the door closure. The power, control and indicators are to be operable in the event of main power failure. Particular care is to be paid to minimising the effect of control system failure.

2.3.7 As an alternative to the sliding doors required by *Pt 3, Ch 4, 2.3 Watertight doors 2.3.6*, special consideration will be given to the fitting of hinged watertight doors where it can be shown that they are as effective as the sliding type. A suitable log-book system is to be operated to ensure that such doors remain closed except when in use for access.

2.3.8 Subject to the requirements of *Pt 3, Ch 4, 2.3 Watertight doors 2.3.6* and *Pt 3, Ch 4, 2.3 Watertight doors 2.3.7*, hinged watertight doors of approved pattern may be fitted in 'tween decks in approved positions. The hinges of these doors are to be fitted with a pin or bush of a suitable copper alloy in accordance with the *Rules for the Manufacture, Testing and Certification of Materials*, or of an equivalent material acceptable to Lloyd's Register (hereinafter referred to as 'LR').

2.3.9 No accesses are to be fitted in collision bulkheads. In particular designs where it would be impracticable to arrange access to the fore peak other than through the collision bulkhead, access may be permitted subject to special consideration. Where accesses are provided, the openings are to be as small as practicable and positioned as far above the design waterline as possible. The closing appliances are to be watertight, open into the fore peak compartment and consideration will be given to operation from one side only.

2.4 Pipe and cable ducts, ventilation trunks and other penetrations

2.4.1 Where subdivision and damage stability requirements apply and where penetration of watertight divisions by pipes, ducts, trunks or other penetrations is necessary, arrangements are to be made to maintain the watertight integrity.

2.4.2 Ventilators from deep tanks and tunnels passing through 'tween decks are to have scantlings suitable for withstanding pressures to which they may be subjected, and are to be made watertight.

■ *Section 3*
Double bottom openings

3.1 General

3.1.1 Provision is to be made for the free passage of air and water from all parts of the tanks to the air pipes and suctions, account being taken of the pumping rates required.

3.1.2 Adequate access is also to be provided to all parts of the double bottom for future maintenance, surveys and repairs. The edges of all openings are to be smooth.

3.2 Requirements

3.2.1 A plan showing the location of manholes and access openings within the double bottom is to be submitted. Attention is to be given to any relevant Statutory Requirements of the National Authority of the country in which the craft is to be registered.

3.2.2 The number and positioning of manholes are to be such that access under service conditions is neither difficult nor dangerous. Attention is to be given to any relevant international regulations regarding the minimum size of access openings.

3.2.3 Manholes and their covers are to be of an approved design or in accordance with a recognised National or International Standard.

3.2.4 The size of opening is not, in general, to exceed 50 per cent of the double bottom depth, unless edge reinforcement is provided. In way of outboard ends of floors and fore and aft girders at transverse bulkheads, the number and size of holes are to be kept to a minimum, and the openings are to be circular or elliptical. Edge stiffening may be required in these positions.

3.2.5 Manholes, lightening holes and other cut-outs are to be avoided in way of concentrated loads and areas of high shear. In particular, manholes and similar openings are not to be cut in vertical or horizontal diaphragm plates in narrow cofferdams or double plate bulkheads within one-third of their length from either end, nor in floors or double bottom girders close to their span ends, below the heels of pillars, nor in way of mast steps, unless the stresses in the plating and the panel buckling characteristics have been calculated and found satisfactory.

3.2.6 Manholes, lightening holes and other openings are to be suitably framed and stiffened where necessary.

3.2.7 Air and drain holes, notches and scallops are to be in accordance with *Pt 6, Ch 2, 4 Joints and connections* and *Pt 7, Ch 2, 4 Joints and connections* for steel and aluminium alloy construction respectively.

3.3 Alternative arrangements

3.3.1 The Rules are formed on the basis that access to double bottoms will be by means of manholes with bolted covers. However, alternative arrangements will be specially considered.

■ *Section 4*
Side and stern doors and other shell openings

4.1 General

4.1.1 These requirements cover cargo and service doors in the craft side (abaft the collision bulkhead) and stern area, below the freeboard deck and in enclosed superstructures.

4.1.2 For the requirements of bow doors, *see Pt 6, Ch 5, 4 Bow doors* and *Pt 7, Ch 5, 4 Bow doors* for steel and aluminium alloy construction respectively.

4.1.3 Side and stern doors are to be so fitted as to ensure tightness and structural integrity commensurate with their location and the surrounding structure. *See also Pt 3, Ch 1, 6.8 Weathertight 6.8.2* and *Pt 3, Ch 1, 6.9 Watertight 6.9.2*.

4.1.4 In general, the lower edge of door openings are not to be below a line drawn parallel to the freeboard deck at side, which is at its lowest point at least 230 mm above the upper edge of the uppermost Load Line.

4.1.5 When the lower edge is below the uppermost Load Line, the arrangement will be specially considered. Special consideration is to be given to preventing the spread of leakage water over the deck. The reference to the uppermost Load Line is to be taken as the tropical fresh water line.

4.1.6 Doors are generally to be arranged to open outwards, however inward opening doors will be considered provided strongbacks are fitted when the doors are situated in the first two 'tween decks above the waterline.

4.1.7 For passenger craft the following is also applicable:

(a) Gangway, cargo and service ports fitted below the margin line, *see Pt 3, Ch 4, 1.2 Downflooding 1.2.2*, are to satisfy the strength requirements given for side doors in this Section. They are to be effectively closed and secured watertight before the craft leaves port, and are to be kept closed during navigation. Such ports are not to have their lowest point below the deepest subdivision Load Line.
(b) Where the inboard end of a rubbish chute is below the margin line in a passenger craft, the inboard end cover is to be watertight and, in addition to the discharge flap interlock, a screwdown automatic non-return valve is to be fitted in an easily accessible position above the deepest subdivision. The valve is to be controlled from a position above the bulkhead deck and provided with an open/shut indicator, and kept closed when not in use. A suitable notice is to be displayed at the valve position.

4.1.8 Where doors and platforms are fitted in the shell, the structural and watertight integrity of the hull is to be maintained. Such doors and platforms are not to lead directly into the craft and an internal watertight compartment is to be provided in way of the shell openings. The doors and platforms are to be arranged to open outwards. The sill height of the access hull opening is not to be less than 230 mm above the upper edge of the uppermost Load Line and the sill height of the internal access is to be not less than 300 mm higher than the hull sill. Alternative arrangements will be specially considered.

4.1.9 Doors may be of steel, aluminium alloy or FRP construction and are to be efficiently connected to the adjoining structure and of equivalent strength and are to have adequate securing and sealing arrangements. It is recommended that doors are hinged about their forward edges and open outwards. Details are to be submitted for approval. Other materials will be specially considered.

4.1.10 For craft complying with the requirements of this Section, the securing, supporting and locking devices are defined as follows:

(a) A securing device is used to keep the door closed by preventing it from rotating about its hinges or other pivoted attachments to the craft.
(b) A supporting device is used to transmit external and internal loads from the door to a securing device and from the securing device to the craft's structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, that transmits loads from the door to the craft's structure.
(c) A locking device locks a securing device in the closed position.

4.2 Symbols

4.2.1 The symbols used in this Section are defined as follows:

σ = bending stress, in N/mm^2

σ_e = equivalent stress, in N/mm^2

$= \sqrt{\sigma^2 + 3\tau^2}$

τ = shear stress, in N/mm^2

σ_o is defined in *Pt 3, Ch 3, 1.2 General*.

4.3 Scantlings

4.3.1 In general the strength of side and stern doors is to be equivalent to the strength of the surrounding structure.

4.3.2 Door openings in the side shell are to have well rounded corners and adequate compensation is to be arranged with web frames at sides and stringers or equivalent above and below. *See Pt 6, Ch 3, 3 Shell envelope plating*, *Pt 7, Ch 3, 3 Shell envelope plating* and *Pt 8, Ch 3, 3 Shell envelope laminate* for steel, aluminium alloy and composite construction respectively.

4.3.3 Doors are to be adequately stiffened, and means are to be provided to prevent movement of the doors when closed. Adequate strength is to be provided in the connections of the lifting/manoeuvring arms and hinges to the door structure and to the craft structure.

4.3.4 The thickness of the door plating is to be not less than the shell plating calculated with the door stiffener spacing, and in no case to be less than the minimum adjacent shell thickness.

4.3.5 Where stern doors are protected against direct wave impact by a permanent external ramp, the thickness of the stern door plating may be reduced by 20 per cent relative to the requirements of *Pt 3, Ch 4, 4.3 Scantlings 4.3.4*. Those parts of the stern door which are not protected by the ramp are to have the thickness of plating in full compliance with *Pt 3, Ch 4, 4.3 Scantlings 4.3.4*.

4.3.6 The section modulus of horizontal or vertical stiffeners is to be not less than required for the adjacent shell framing using the actual stiffener spacing. Consideration is to be given, where necessary, to differences in fixity between shell frames and door stiffeners.

4.3.7 Where necessary, door secondary stiffeners are to be supported by primary members constituting the main stiffening elements of the door.

4.3.8 The webs of primary members are to be adequately stiffened, preferably in a direction perpendicular to the shell plating.

4.3.9 The buckling strength of primary members is to be specially considered.

4.3.10 All load transmitting elements in the design load path from door through securing and supporting devices into the craft structure, including welded connections, are to be to the same strength standard as required for the securing and supporting devices.

4.4 Doors serving as ramps

4.4.1 Where doors also serve as vehicle ramps, the plating and stiffeners are to be not less than required for vehicle decks. *See Pt 6, Ch 5, 3 Vehicle decks*, *Pt 7, Ch 5, 3 Vehicle decks* and *Pt 8, Ch 5, 3 Vehicle decks* for steel, aluminium alloy and composite construction respectively.

4.4.2 The support structure (including hinges) is to be assessed in accordance with *Pt 6, Ch 5, 2.13 Ramp supporting structure*, *Pt 7, Ch 5, 2.13 Ramp supporting structure* and *Pt 8, Ch 5, 2.13 Ramp supporting structure* for steel, aluminium alloy and composite construction, respectively.

4.5 Closing, securing and supporting of doors

4.5.1 Doors are to be fitted with adequate means of closing, securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure. The hull supporting structure in way of the doors is to be suitable for the same design loads and design stresses as the securing and supporting devices. Where packing is required, the packing material is to be of comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered. Maximum design clearance between securing and supporting devices is not generally to exceed 3 mm.

4.5.2 Securing devices are to be simple to operate and easily accessible. They are to be of an approved type.

4.5.3 Securing devices are to be equipped with mechanical locking arrangements (self locking or separate arrangements), or are to be of gravity type. The opening and closing systems as well as securing and locking devices are to be interlocked in such a way that they can only operate in the proper sequence.

4.5.4 Means are to be provided to enable the doors to be mechanically fixed in the open position taking into account the self weight of the door and a minimum wind pressure. The following minimum wind pressure and direction need to be considered:

- 1,5 kN/m^2 (0,153 tonne-f/m^2) acting on the maximum projected area in the open position. Maximum projected area is to be determined by the projected area of the open door onto the ship’s vertical plane, thereby considering static heel angles of the vessel of up to 15 degrees; and
- 150 N/m^2 acting on the maximum projected area of the open door onto a horizontal plane .

4.5.5 The spacing for cleats or closing devices is not to exceed 2,5 m and cleats or closing devices are to be positioned as close to the corners as practicable. Alternative arrangements for ensuring weathertight sealing will be specially considered. Where special consideration is made, the maximum deflection of the door edge between the cleats under the pressure loading (internal/ external for outside/inside opening doors respectively) is to be limited to 1/1000 of the cleats distance, applying the load specified in *Pt 3, Ch 4, 4.5 Closing, securing and supporting of doors 4.5.11* acting to push the door open.

4.5.6 Doors with a clear opening area of 12 m^2 or greater are to be provided with closing devices operable from a remote control position. Doors which are located partly or totally below the freeboard deck with a clear opening area greater than 6m^2 are to be provided with an arrangement for remote control from a position above the freeboard deck. This remote control is provided for the:

(a) Closing and opening of the doors.
(b) Associated securing and locking devices.

4.5.7 The location of the remote control panel is to be such that the opening/closing operation can be easily observed by the operator or by other suitable means such as closed circuit television.

4.5.8 A notice is to be displayed at the operating panel stating that the door is to be fully closed and secured preferably before, or immediately prior to, the craft leaving the berth and that this operation is to be entered in the craft's log. This notice is to be supplemented by warning indicator lights indicating if any door is not fully closed, secured and locked.

4.5.9 Means are to be provided to prevent unauthorised operation of the doors.

4.5.10 Where hydraulic securing devices are applied, the system is to be mechanically lockable in the closed position so that in the event of hydraulic system failure, the securing devices will remain locked. The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits when in the closed position.

4.5.11 The design force considered for the scantlings of primary members, securing and supporting devices of side shell doors and stern doors are to be taken not less than:

(a) Design forces for securing or supporting devices of doors opening inwards:

External force:

$$F_e = Ap_e + F_p \text{ kN}$$

Internal force:

$$P_i = P_o + 10W \text{ kN}$$

(b) Design forces for securing or supporting devices of doors opening outwards:

External force:

$$F_e = Ap_e \text{ kN}$$

Internal force:

$$P_i = P_o + 10W + F_p \text{ kN}$$

(c) Design forces for primary members:

External force:

$$F_e = Ap_e \text{ kN}$$

Internal force:

$$P_i = P_o + 10W \text{ kN}$$

whichever is the greater.

The symbols used are defined as follows:

p_e = external sea pressure, not to be taken less than 25 kN/m^2

A = total area of door opening, in m^2 to be determined on the basis of the load area taking account of the direction of pressure

W = weight of the door, in tonnes

F_p = total packing force, kN. When packing is fitted, the packing force per unit length is to be specified, normally not to be taken less than: 5 kN/m

P_o = the greater of P_c and 5A kN

P_c = accidental force, in kN, due to loose cargo, etc. to be uniformly distributed over the area A and not to be taken less than 300 kN. For small doors such as bunker doors and pilot doors, the value of P_c may be taken as zero, provided an additional structure such as an inner ramp is fitted, which is capable of protecting the door from accidental force due to loose cargoes.

4.6 Systems for indication and monitoring

4.6.1 The following requirements apply to doors in the boundaries of special category spaces or ro-ro spaces, as defined in the SOLAS Convention, through which such spaces may be flooded. For cargo craft, where no part of the door is below the uppermost waterline and the area of the door opening is not greater than 6 m^2, then the requirements of this Section need not be applied.

4.6.2 Separate indicator lights and audible alarms are to be provided on the navigation bridge and on each operating panel to indicate that the doors are closed and that their securing and locking devices are properly positioned. The indication panel is to be provided with a lamp test function. It is not to be possible to turn off the indicator light.

4.6.3 The indicator system is to be designed on the fail safe principle and is to indicate by visual alarms if the door is not fully closed and not fully locked, and by audible alarms if securing devices become open or locking devices become unsecured. The power supply for the indicator system is to be independent of the power supply for operating and closing the doors and is to be provided with a back-up power supply. The sensors of the indicator system are to be protected from water, ice formation and mechanical damages.

4.6.4 The indication panel on the navigation bridge is to be equipped with a mode selection function `harbour/sea voyage', so arranged that audible alarm is given if the craft leaves harbour with side shell or stern doors not closed or with any of the securing devices not in the correct position.

4.6.5 For passenger craft, a water leakage detection system with audible alarm and television surveillance are to be arranged to provide an indication to the navigation bridge and to the engine control room of any leakage through the doors. For cargo craft, a water leakage detection system with audible alarm is to be arranged to provide an indication to the navigation bridge.

4.7 Design of securing and supporting devices

4.7.1 Securing devices and supporting devices are to be designed to withstand the forces given in *Pt 3, Ch 4, 5.11 Standard designs* using the permissible stresses given in *Table 4.4.1 Permissible stress for bolts, closing and supporting devices*. The terms `securing device' and `supporting device' are defined in *Pt 6, Ch 5, 4.3 Symbols and definitions*.

4.7.2 The nominal tensile stress in way of threads of bolts is not to exceed the permissible stress given in *Table 4.4.1 Permissible stress for bolts, closing and supporting devices*. The arrangement of securing and supporting devices is to be such that threaded bolts are not to carry support forces.

4.7.3 For steel to steel bearings in securing and supporting devices, the normal bearing pressure is not to exceed $0{,}8\sigma_o$. For other bearing materials, the permissible bearing pressure is to be determined according to the manufacturer's specification. The normal bearing pressure is to be calculated by dividing the design force by the projected bearing area.

4.7.4 The distribution of the reaction forces acting on the securing and supporting devices may require to be supported by direct calculations taking into account the flexibility of the hull structure and the actual position and stiffness of the supports. Small and/or flexible devices, such as cleats, intended to provide load compression of the packing material are not generally to be included in these calculations.

4.7.5 Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be considered in the calculation of the reaction forces acting on the devices.

4.7.6 The number of securing and supporting devices is generally to be the minimum practicable whilst complying with *Pt 3, Ch 4, 4.5 Closing, securing and supporting of doors 4.5.3* and taking account of the available space in the hull for adequate support.

Table 4.4.1 Permissible stress for bolts, closing and supporting devices

Material	Closing and supporting devices			Thread of bolts
	Direct stress N/mm^2	Shear stress N/mm^2	Equivalent stress N/mm^2	Direct stress N/mm^2
Steel	$\frac{120}{k_s}$	$\frac{80}{k_s}$	$\frac{150}{k_s}$	$\frac{120}{k_s}$
Aluminium	$\frac{64}{k_a}$	$\frac{43}{k_a}$	$\frac{80}{k_a}$	$\frac{64}{k_a}$
Note $k_s = \frac{235}{\sigma_o}$, σ_o as defined in Ch 3,*Pt 3, Ch 3, 1.2 General 1.2.1* $k_a = \frac{120}{\sigma_{ya}}$, σ_{ya} as defined in Ch 3,*Pt 3, Ch 3, 1.2 General 1.2.2*				

4.7.7 The arrangement of securing devices and supporting devices in way of these securing devices is to be designed with redundancy so that in the event of failure of any single securing or supporting device the remaining devices are capable of withstanding the reaction forces, without exceeding, by more than 20 per cent, the permissible stresses referred to in *Pt 3, Ch 4, 4.7 Design of securing and supporting devices 4.7.1*.

4.8 Operating and Maintenance Manual

4.8.1 An Operating and Maintenance Manual for the doors is to be provided on board and is to contain necessary information on:

(a) main particulars and design drawings;
(b) service conditions, (e.g. service area restrictions, acceptable clearances for supports);
(c) maintenance and function testing;
(d) register of inspections and repairs.

This Manual is to be submitted to LR for review, and is to contain a note recommending that recorded inspections of the door supporting and securing devices be carried out by the craft's staff at monthly intervals or following incidents that could result in damage, including heavy weather or contact in the region of the doors. Any damages recorded during such inspections are to be reported to LR.

4.8.2 Documented operating procedures for closing and securing the doors are to be kept on board and posted at an appropriate place.

4.9 Engine removal arrangements

4.9.1 Where portable plates are required for unshipping machinery, or for other similar reasons, they may be accepted provided they are of equivalent strength to the unpierced structure and are secured by gaskets and close spaced bolts. The pitch spacing of the bolts will be specially considered depending on the hatch stiffening and support arrangements but should not exceed ten diameters.

4.10 Testing on completion

4.10.1 The items listed in *Table 1.7.1 Testing requirements* in Chapter 1 are to be hose tested to the satisfaction of the Surveyor.

■ *Section 5*
Hatches on exposed decks

5.1 General

5.1.1 This Section applies to small hatchways or access openings in the positions indicated in *Figure 4.5.1 Arrangement of doors, sills and hatch coamings*.

5.1.2 The number and size of hatchways and other access openings are to be kept to the minimum consistent with the satisfactory operation of the craft.

5.1.3 Hatch covers are to be weathertight when closed, of substantial construction and generally hinged. The means of securing are to be such that weathertightness can be maintained in any sea condition. Details are to be submitted for approval.

5.1.4 Hatch covers may be of steel, aluminium alloy or FRP construction. Where toggles are fitted, their diameter and spacing are to be in accordance with an ISO Standard or equivalent.

5.1.5 Hatches on the weatherdeck in the forward $0,25L_R$ or to machinery spaces are to be hinged on the forward side.

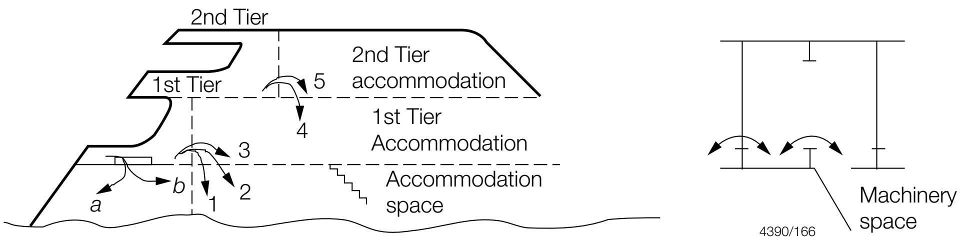


Figure 4.5.1 Arrangement of doors, sills and hatch coamings

Table 4.5.1 Height of hatch coamings

Location/Access	Height (mm) (*see* Note 2)
(a) Weather deck/machinery compartment	460
(b) Weather deck/lower deck accommodation	150 230
(c) Weather deck/cargo hold	460
Note 1. For locations (a) and (b), *see Figure 4.5.1 Arrangement of doors, sills and hatch coamings*. Note 2. Reduced coaming heights will be specially considered based on a craft's service area restriction notation.	

5.2 Coaming heights

5.2.1 Hatch coamings are to have a height above the deck surface in accordance with *Table 4.5.1 Height of hatch coamings*. Lower heights may be considered in relation to operational requirements and the nature of the spaces to which access is given.

5.2.2 Flush hatches will be specially considered.

5.2.3 Rope hatches may be accepted with reduced coamings, but generally not less than 380 mm, provided they are well secured and opened only at the Master's discretion. A suitable notice is to be displayed at the hatch.

5.3 Scantlings

5.3.1 Hatch covers are to be of equivalent strength to the deck on which they are fitted.

5.3.2 The thickness of the coamings is to be not less than the Rule thickness for the deck in the positions in which they are fitted. Stiffening of the coaming is to be appropriate to its length and height.

5.3.3 The covers are to be adequately stiffened.

5.4 Closing devices

5.4.1 Hinges are not to be used as securing devices unless specially considered.

5.4.2 To facilitate a swift and safe means of escape to the lifeboat and life raft embarkation deck, the following provisions apply to overhead hatches fitted along the escape routes addressed by *Regulation 13 - Means of escape*:

(a) Escape hatches and their securing devices are to be of a type which can be opened from both sides;
(b) The maximum force needed to open the hatch cover is not to exceed 150 N; and
(c) The use of a spring counterbalance, equalising or any other suitable device on the hinge side to reduce the force needed for opening is acceptable.

5.5 Engine removal hatches

5.5.1 Where portable plates are required in decks for unshipping machinery, or for other similar reasons, they may be accepted provided they are of equivalent strength to the unpierced deck and are secured by gaskets and closely spaced bolts. The pitch spacing of the bolts will be specially considered depending on the hatch stiffening and support arrangements but should not exceed ten diameters.

5.6 Structural details

5.6.1 Various structural details for hatchways and access openings are given in the LR *Guidance Notes for Structural Details*.

5.7 Effective support for large hatch covers

5.7.1 The weight of hatch covers and any loads carried thereon, together with inertial forces generated by craft motions, are to be effectively transmitted to the craft structure. This may be achieved by continuous structural contact of the hatch cover with the craft structure or by means of defined bearing pads. The bearing pressure will be specially considered depending on the construction material.

5.8 National Authority requirements

5.8.1 The height of the hatch coaming may be subject to additional requirements of the National Authority.

5.9 Exceptions

5.9.1 Subject to the agreement of LR exceptions may be given to the requirements of this Section where they interfere with the operation of the craft. Such exceptions will be specially considered.

5.10 Testing upon completion

5.10.1 The items listed in *Table 1.7.1 Testing requirements* in Chapter 1, are to be hose tested to the satisfaction of the Surveyor.

5.11 Standard designs

5.11.1 Standard designs of hatches may be accepted, provided they are designed and manufactured in accordance with the requirements of a recognised National or International Standard which gives reasonable equivalence to the requirements of this Section.

5.11.2 Standard proprietary flush hatches, not exceeding 650 mm x 650 mm clear opening, which are of a type holding a valid Type Approval by LR, may be accepted for under deck access in non-working areas of craft below 24 m in length, L_R, dependent upon the Service Group Notation. Where the hatch type is not type approved, full details, including the material specification, are to be submitted for approval in each case.

5.12 Novel features

5.12.1 Hatchways of novel or unusual design will be specially considered.

■ *Section 6* Miscellaneous openings

6.1 General

6.1.1 This Section gives requirements for external doors, manholes and flush scuttles, hatchways within enclosed superstructures or 'tween decks and companionways, doors and accesses on weather decks.

6.1.2 Those items listed in *Table 1.7.1 Testing requirements* in Chapter 1, are to be hose tested to the satisfaction of the Surveyor.

6.2 External doors

6.2.1 Door sills are to have a height above the deck surface in accordance with *Table 4.6.1 Height of door sills*.

6.2.2 Reduced sill heights for doors will be considered as follows:

(a) dependent upon the service group notation,
(b) for doors which will only be used when the craft is in harbour, or calm water,
(c) where the sill height interferes with the operation of the craft,
(d) where doors do not give access to spaces below the freeboard deck.

6.2.3 The height of the door sill may be subject to additional requirements of the National Authorities.

6.2.4 Where the sill heights do not comply with the requirements of *Table 4.6.1 Height of door sills*, interior deck openings are to be treated as if they were exposed on the weather deck.

Table 4.6.1 Height of door sills

Position/access	Height (mm)
(1) Weather deck/machinery compartment *See* Note 2	460
(2) Weather deck/lower accommodation	230
(3) Weather deck/1st tier accommodation	150
(4) 1st tier/1st tier accommodation	100
(5) 1st tier/2nd tier accommodation	50
Note 1. For positions (1), (2), etc. *see Figure 4.5.1 Arrangement of doors, sills and hatch coamings*. Note 2. Where the access to the machinery space is protected by an outer weathertight door, the inner door sill or hatch coaming may be 230 mm high in association with an outer sill height of 230 mm.	

6.3 Manholes and flush scuttles

6.3.1 Manholes and flush scuttles fitted in Positions 1 and 2, or within superstructures other than enclosed superstructures, are to be closed by substantial covers capable of being made watertight. Unless secured by closely spaced bolts, the covers are to be permanently attached.

6.4 Hatchways within enclosed superstructures or 'tween decks

6.4.1 The requirements of *Pt 3, Ch 4, 5 Hatches on exposed decks* are to be complied with where applicable.

6.4.2 Access hatches within a superstructure or deckhouse in Position 1 or 2 need not be provided with means for closing if all openings in the surrounding bulkheads have weathertight closing appliances.

6.5 Companionways, doors and accesses on weather decks

6.5.1 Companionways on exposed decks are to be of equivalent construction, weathertightness and strength to a deckhouse in the same position and effectively secured to the deck.

6.5.2 Access openings in:

(a) Bulkheads at ends of enclosed superstructures,
(b) Deckhouses or companionways protecting openings leading into enclosed superstructures or to spaces below the freeboard deck, and
(c) Deckhouses on a deckhouse protecting an opening leading to a space below the freeboard deck,

may be fitted with doors of steel, aluminium alloy, FRP or other equivalent material, permanently and strongly attached to the bulkhead and framed, stiffened and fitted so that the whole structure is of equivalent strength to the unpierced bulkhead, and weathertight when closed. The doors are to be gasketed and secured weathertight by means of clamping devices or equivalent arrangements, permanently attached to the bulkhead or to the door. Doors are generally to open outwards and are to be capable

of being operated and secured from both sides. The sill heights are to be as required by *Pt 3, Ch 4, 6.2 External doors*. Double doors are to be equivalent in strength to the unpierced bulkhead, and in Position 1, a centre pillar is to be provided which may be portable.

6.5.3 Elsewhere doors may be of hardwood or equivalent material and are to be of equivalent strength to the unpierced bulkhead.

6.5.4 Portlights or windows in doors are to comply with the requirements given in *Pt 3, Ch 4, 7 Portlights, windows and viewing ports, skylights and glass walls*. Deadlights or storm covers may be external.

6.5.5 When the closing appliances of openings in superstructures and deckhouses do not comply with *Pt 3, Ch 4, 6.5 Companionways, doors and accesses on weather decks 6.5.2*, interior deck openings are to be treated as if exposed on the weather deck.

6.5.6 Doors on the weather deck (first tier) protecting direct access to machinery spaces are to be of substantial construction in accordance with approved plans or a recognised National or International Standard. They are to be permanently attached to the casing, outward opening and gasketed weathertight with a minimum of six clips and have a sill height in accordance with *Pt 3, Ch 4, 6.2 External doors*.

6.5.7 Doors on the weather deck to accommodation or spaces protecting access below are to be as required by *Pt 3, Ch 4, 6.5 Companionways, doors and accesses on weather decks 6.5.6* with a minimum of four clips.

6.5.8 Where wood doors are proposed on the weather deck in lieu of doors as per *Pt 3, Ch 4, 6.5 Companionways, doors and accesses on weather decks 6.5.7*, they are to be strongly constructed of hardwood not less than 45 mm thick and double gasketed. For doors in exposed locations, additional securing arrangements by slip bolts, clamps or equivalent will be required. These doors are not to be the sole means of entry or exit from the space. Where these doors may be required to be used as a means of escape in an emergency situation, the additional security arrangements are to be operable from both sides.

6.5.9 FRP doors are not to be fitted in access openings where `A', `B' or `C' class fire integrity is required, or in engine room casings.

6.5.10 Doors in the second tier are to be as required by *Pt 3, Ch 4, 6.5 Companionways, doors and accesses on weather decks 6.5.6* with a minimum of four clips.

6.6 Underwater lights

6.6.1 Positions of any underwater lights fitted on board are to be shown on the ‘layout of hull penetrations plan’, *see Pt 3, Ch 4, 2.4 Pipe and cable ducts, ventilation trunks and other penetrations 2.4.1*. Details of local arrangements are to be submitted.

6.6.2 Where bimetallic connections are made, involving dissimilar metals, measures are to be incorporated to preclude galvanic corrosion.

6.6.3 All non-metallic sealing arrangements are to be suitable for continued immersion in a marine environment. Arrangements and application are to be in accordance with the sealant manufacturer’s published guidelines and relevant LR Rules.

6.6.4 Underwater lighting arrangements are to be such that there are primary and secondary means of protection to maintain the watertight integrity of the craft. In some installations this may be achieved by the fitting of a small cofferdam surrounding the primary barrier. Alternative arrangements will be specially considered, and are to ensure that failure of the primary barrier will not affect the survivability or safe operation of the craft. Typically the primary barrier is not to be located outside of the shell envelope plating.

6.6.5 Underwater lighting arrangements which are not covered by Type Approval Certification will require prototype testing in order to confirm the structural integrity and watertightness of the primary and secondary barriers. The test pressure is to be four times the design pressure at the proposed location. Tests are to be carried out to the satisfaction of the Surveyor.

■ *Section 7*
Portlights, windows and viewing ports, skylights and glass walls

7.1 General

7.1.1 This Section gives the requirements for portlights, windows, viewing ports, sliding glass doors, glass walls, skylights, glazing materials, deadlights and storm covers.

7.1.2 Side scuttles and portholes are considered to be portlights.

7.1.3 A plan showing the location of portlights, windows, viewing ports, skylights and glass walls is to be submitted.

7.1.4 Portlights and windows, together with their glazing and deadlights if required, are to be of an approved design or in accordance with a recognised National or International Standard.

7.1.5 Glass in portlights, windows and skylights is to be thermally toughened safety glass with a thickness in accordance with approved plans or a recognised National or International Standard relative to their location.

7.1.6 Where consideration is given to the use of glazing materials other than thermally toughened glass, the thickness and arrangements are to take account of any different material properties and are to be individually approved and tested as appropriate or be in accordance with LR's Type Approval Procedure.

7.1.7 The use of rubber frames is not generally acceptable.

7.1.8 In position 2, cabin bulkheads and doors are considered effective between portlights or windows and access below.

7.1.9 Side scuttles are defined as being round or oval openings with an area not exceeding 0.16 m^2. Round or oval openings having areas exceeding, 0,16 m^2 shall be treated as windows.

7.1.10 Windows are defined as being rectangular openings generally, having a radius at each corner relative to the window size and round or oval openings with an area exceeding 0,16 m^2.

7.2 Applications

7.2.1 As indicated in *Pt 3, Ch 4, 1.1 Application*. *See also Pt 4 Additional Requirements for Yachts* for additional requirements for yachts.

7.3 National Authority requirements

7.3.1 In addition to the requirements of this Section, where relevant, care is to be given to the statutory requirements of the National Authority.

7.4 Portlights

7.4.1 Portlights are to be in accordance with a recognised National or International Standard or of a type accepted for the respective position and having a valid LR Type Approval certificate. Where the portlight is not type approved, full details are to be submitted for approval in each case.

7.4.2 Portlights may be round, elliptical or elongated and are to be of substantial construction.

7.4.3 Portlights are not to be fitted in machinery spaces.

7.4.4 No portlight is to be fitted in such a position that its sill is below a line drawn parallel to the freeboard deck at side and having its lowest point 2,5 per cent of the breadth, *B*, above the load waterline corresponding to the summer freeboard (as defined in *Pt 3, Ch 1, 6.2 Principal particulars 6.2.7*), or 500 mm, whichever is the greater distance, *see Figure 4.7.1 Position of portlights*.

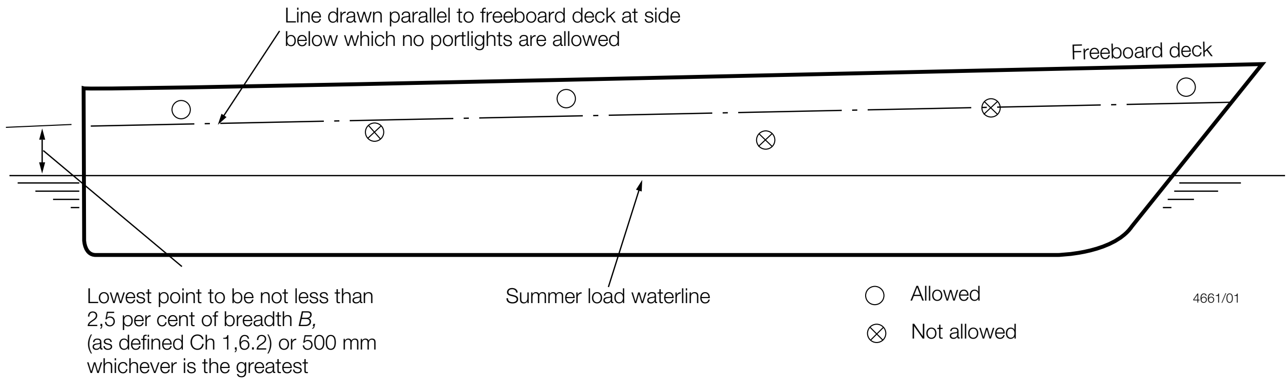


Figure 4.7.1 Position of portlights

7.4.5 Deadlights or storm covers for portlights are to be provided in accordance with *Pt 3, Ch 4, 7.12 Deadlights and storm covers*.

7.5 Windows

7.5.1 Windows are to be in accordance with a recognised National or International Standard or of a type accepted for the respective position and having a valid LR Type Approval certificate.

7.5.2 Where the window is not type approved, full details are to be submitted for approval in each case and the prototype tested in accordance with the requirements of *Pt 3, Ch 4, 7.5 Windows 7.5.3* to *Pt 3, Ch 4, 7.5 Windows 7.5.5*.

7.5.3 A hydrostatic test is to be carried out in order to examine watertightness of windows fitted in the side shell. A design pressure p, where p is given in *Pt 3, Ch 4, 7.8 Toughened safety glass thickness 7.8.1*, is to be applied to the external face of the window and maintained for at least 15 minutes.

7.5.4 A structural test is to be carried out in order to examine the capability of the frame, and glazing retaining arrangements. A design pressure $4p$, where p is given in *Pt 3, Ch 4, 7.8 Toughened safety glass thickness 7.8.1* is to be applied to the external face of the window, utilising an aluminium alloy plate of appropriate temper and thickness to simulate the flexural response in lieu of the glazing. A full-scale test with actual glazing in place may be acceptable provided that the stresses induced are within allowable limits. Details of the calculations made and testing procedures are to be submitted for review prior to the test. Alternative means of demonstrating adequacy of frame, mullions and the retaining arrangement for the glazing may be specially considered.

7.5.5 Equivalent proposals for testing will be considered. Where alternative testing procedures are proposed, these are to be agreed with LR before commencement.

7.5.6 Window glazing is, in general, to be toughened safety glass, fitted in substantial frames supporting both faces of the glass and effectively secured to the structure. Metal to glass contact is to be avoided.

7.5.7 In general, no windows are to be fitted in the following locations:

(a) below the freeboard deck;
(b) in the first tier end bulkheads or sides of enclosed superstructures; or
(c) in first tier deckhouses that are considered buoyant in the stability calculations.

7.5.8 Wheelhouse window glazing is to be toughened safety glass, or where it is of laminated or sandwich construction, the surface layers are to be of toughened safety glass.

7.5.9 Large windows in the aft end of superstructure or deckhouses will be specially considered.

7.5.10 Openings in the shell for windows are to have well rounded corners.

7.5.11 Storm covers or deadlights for windows are to be provided in accordance with *Pt 3, Ch 4, 7.12 Deadlights and storm covers*.

7.6 Viewing ports

7.6.1 In general, viewing ports are not to be fitted in the bottom shell of high speed craft.

7.6.2 Viewing ports are to be watertight and of substantial construction in accordance with approved plans.

7.6.3 Glazing is to be fitted in substantial frames supporting both faces of the glazing and effectively secured to the hull structure.

7.6.4 Where practicable, viewing ports are to be fitted with efficient, hinged, deadlights which are capable of being effectively closed and secured watertight, with or without the glazing in place.

7.6.5 Hydrostatic pressure tests are to be carried out to confirm that the proposed construction, when fitted in the hull, is able to withstand a pressure of four times the design pressure and remain watertight. Where a deadlight is fitted, this test is also to be carried out with the glazing removed and the deadlight closed.

7.7 Sliding glass doors or `glass walls'

7.7.1 Large glass doors or windows in the aft end of superstructures and deckhouses and other large glass structures forming the sides, ends or roofs of deckhouses will be specially considered.

7.7.2 When sliding glass doors are provided, or a `glass wall' which includes an access, an alternative access or exit from the space is to be provided and the arrangements are to be in accordance with approved plans and weathertight commensurate with their position. Sill heights are, in general, to be in accordance with *Pt 3, Ch 4, 6.2 External doors*.

7.7.3 The glazing is to be toughened safety glass, or equivalent, and of substantial thickness in accordance with *Pt 3, Ch 4, 7.8 Toughened safety glass thickness*, *Pt 3, Ch 4, 7.9 Laminated glass thickness* or *Pt 3, Ch 4, 7.10 Other glazing materials* as appropriate.

7.7.4 Storm covers or roller shutters are to be provided in accordance with *Pt 3, Ch 4, 7.12 Deadlights and storm covers 7.12.11*.

7.8 Toughened safety glass thickness

7.8.1 The thickness, *t*, of toughened safety glass is to be not less than 6 mm or that given by the following expression, whichever is the greater:

for glazing of rectangular form

$$t = 0,005b\sqrt{\beta\, p} \text{ mm}$$

for glazing of circular form

$$t = 0,00559r\sqrt{p} \text{ mm}$$

where

r = radius of the glazing, in mm

b = length of shorter side of glazing, in mm

p = design pressure in kN/m^2, as defined in *Pt 5, Ch 3, 3.1 Hull structures* and *Pt 5, Ch 4, 3.1 Hull structures*

β = $-0,17 + 0,54A_R - 0,078A_R^2$ for $A_R \leq 3$

= 0,75 for $A_R > 3$

A_R = aspect ratio of window

= a/b

a = length of longer side of window, in mm

7.8.2 For windows of trapezoidal form, the length of window, *a*, is to be taken as the mean of the length of the longer sides. The value of *b*, the length of the shorter side, may be similarly determined.

7.9 Laminated glass thickness

7.9.1 Laminated toughened safety glass may be used having a thickness greater than the single plate toughened safety glass for the same size window, as given by:

$$t_s^2 = t_{i1}^2 + t_{i2}^2 + \ldots\ldots + t_{in}^2 \text{ mm}$$

where

n = number of laminates

t_i = thickness of laminate, in mm

t_s = thickness of equivalent single plate, in mm

Alternative arrangements that do not meet the above thickness requirement will be specially considered, provided that equivalent strength and bending stiffness to that of a single, thermally toughened pane of thickness, t_s, can be demonstrated in a four-point bending test in accordance with EN-ISO 1288-3 or an equivalent recognised National or International Standard, using no fewer than ten samples. The lower limit of the 90 per cent confidence level interval for the laminated pane shall not be less than the same for monolithic toughened safety glass. Comparison shall be made based on a reference load test area per sample of 0,072 m^2. When samples tested under other standards than ISO 1288-3 are smaller, the confidence level used in the statistical reduction must be increased accordingly:

probability = $1{,}0 - (1{,}0 - 0{,}90)^{(0{,}072/a_{sample})}$

The minimum number of samples tested must be suitably increased to get a representative result:

n_{min} = $10 * 0{,}072/a_{sample}$

where

a_{sample} = area of the sample between the inner rollers.

Small scale punch test or ring-in-ring test methods shall not be used.

7.10 Other glazing materials

7.10.1 Materials other than glass may be used for windows, except for those in the wheelhouse, with the thickness obtained by multiplying the thickness for toughened safety glass by a factor of 1,3 for polycarbonate and 1,5 for acrylic. Consideration will be given to composite and multi-layer constructions where documented results of a pressure test confirm that the proposed construction, when fitted in its appropriate frame, is able to withstand a test pressure of four times the design pressure and remain watertight.

7.11 Openings and framing requirements

7.11.1 The strength and dimensions of the frame section are to be appropriate to the size of the window, the type of glazing being used and its method of bedding. The glazing is to be secured to its frame in accordance with the manufacturer's instructions and recommendations; metal to glass contact is to be avoided.

7.11.2 Rubber frames are not acceptable for windows in Positions 1 and 2, and are not generally acceptable in any other position in external casings. Any proposals to fit rubber frames are to be submitted for consideration. The proposed locations, frame dimensions, glass thicknesses and the results of any tests carried out, are to be forwarded.

7.12 Deadlights and storm covers

7.12.1 Portlights fitted to spaces below the weather deck, or to spaces within enclosed superstructures, are to be fitted with efficient, hinged, inside deadlights which are capable of being effectively closed and secured watertight below the weather deck and weathertight above the weather deck.

7.12.2 In service craft less than 24 m Rule length, L_R, and yachts, portlights in the hull in way of accommodation may have portable deadlights, provided that they are stored adjacent to the portlight and can be readily fitted. Also, in the case of these craft, portlights in superstructures or deckhouses do not require to have deadlights, unless on the weather deck in exposed positions or protecting direct access below, in which case, they are to be provided with deadlights or storm covers.

7.12.3 For craft in **Service Group G1**, storm covers or deadlights are generally not required for windows or portlights in superstructures or deckhouses.

7.12.4 For craft in **Service Group G2**, storm covers or deadlights are required for:

(a) 50 per cent of the windows and portlights in the front of the superstructure or deckhouse on the weather deck.
(b) The windows and portlights in the forward half of the superstructure or deckhouse side on the weather deck, except where these are interchangeable port and starboard, in which case a sufficient number to fit the forward half of one side is to be provided.
(c) Each different size of window and portlight.

7.12.5 For craft in **Service Groups G2A and G3**, storm covers or deadlights are required for:

(a) All windows and portlights in the front of the superstructure or deckhouse on the weather deck.
(b) All windows and portlights in the sides of the superstructure or deckhouse on the weather deck, except where they are interchangeable port and starboard, in which case a sufficient number to fit any one side are to be provided.
(c) Each different size of window and portlight.

7.12.6 For craft in **Service Groups G4** and **G5**, storm covers or deadlights are required as follows:

(a) If fitted in a deckhouse in Position 1, windows are to be provided with strong, hinged, weathertight storm covers. However, if there is an opening leading below deck in this deckhouse, this opening is to be treated as being on an exposed deck and is to have weathertight protection.

(b) Portlights and windows at the shell in Position 2, protecting direct access below, are to be provided with strong permanently attached deadlights.

(c) Portlights and windows at the shell in Position 2, not protecting direct access below, are to be provided with strong portable steel covers for 50 per cent of each size, with means for securing at each window.

(d) Portlights and windows set inboard from the shell in Position 2, protecting direct access below, are either to be provided with strong permanently attached deadlights or, where they are accessible, strong permanently attached external storm covers instead or internal deadlights.

(e) Portlights and windows set inboard from the shell in Position 2, not protecting direct access below, do not require deadlights or storm covers.

(f) Windows in the shell, located at least one standard height of superstructure above the lowest Position 2 deck, are to be provided with strong portable internal storm covers for 25 per cent of each size, with means of securing being provided at each window.

(g) Where windows are permitted in an exposed bulkhead on the weather deck in the forward $0,25L_{L}$, strong external storm covers are to be provided, which may be portable and stored adjacent.

7.12.7 Deadlights and storm covers are not required for second tier portlights or windows in deckhouses without direct access below.

7.12.8 Where the wheelhouse is in Position 2, in lieu of storm covers being provided for the wheelhouse windows, a weathertight cover, fitted to a coaming of not less than 230 mm in height around the internal stairway opening within the wheelhouse, may be accepted. If this arrangement is accepted, adequate means of draining the wheelhouse are to be provided.

7.12.9 If necessary, for practical considerations, the storm covers may be in two parts.

7.12.10 Deckhouses situated on a raised quarter deck may be treated as being in Position 2 as far as the provision of deadlights is concerned, provided the height of the raised quarter deck is equal to, or greater than the standard height.

7.12.11 Sliding glass doors are to be provided with storm covers of strong construction, or, in the case of a `glass wall', this may be protected by a strongly constructed roller shutter or equivalent, which can be readily lowered and secured to provide adequate protection. When necessary, additional portable supports are to be provided for the cover. The arrangements are to be in accordance with approved plans. Alternative arrangements will be specially considered. In lieu of a weathertight coaming for the cover, adequate drainage is to be provided between the cover and the glass which may be in the form of a sump drained overboard, with a grating over.

7.12.12 Deadlights and storm covers are to be weathertight and of equivalent strength to the surrounding structure.

7.12.13 Portable deadlights and storm covers are to be clearly marked to indicate which portlights or windows they fit and stowed in such a way as to be readily fitted.

7.13 Emergency exits

7.13.1 Portlights or windows intended as emergency escapes are to be capable of being opened from both sides and have a minimum clear opening of 600 mm x 600 mm.

7.14 Skylights

7.14.1 Skylights, where fitted, are to be of substantial construction and securely attached to their coamings. The height of the lower edge of opening is to be as required by *Pt 3, Ch 4, 5.2 Coaming heights 5.2.1*. The scantlings of the coaming are to be as required by *Pt 3, Ch 4, 5.3 Scantlings 5.3.2*. The thickness of glazing in fixed or opening skylights is to be appropriate to its size and position as required for portlights or windows. Glazing in any position is to be protected from mechanical damage, and where fitted in Positions 1 or 2 (as defined in *Pt 3, Ch 1, 6.10 Position 1 and Position 2*) is to be provided with robust deadlights or storm covers permanently attached.

7.15 Testing on completion and installation

7.15.1 In order to demonstrate that the requirements of this Section are met the closing arrangements are to be operated under working conditions to the satisfaction of the Surveyor.

7.15.2 The items listed in *Table 1.7.1 Testing requirements*, in Chapter 1, are to be hose tested to the satisfaction of the Surveyor.

7.16 Bonded windows and side scuttles

7.16.1 A ‘bonded window or bonded side scuttle’ is one in which the glazing material is secured in its frame from the outside of the ship by glue or other adhesive material. No mechanical fixing is provided for the glazing. Bonded windows and bonded side scuttles are to comply with the requirements of *Pt 3, Ch 4, 7.5 Windows* and *Pt 3, Ch 4, 7.4 Portlights* respectively, in addition to the requirements in this Section. Proposals to secure glazing from the inside of the ship are to be specially considered using the requirements in this Section as a basis. It should be noted that bonding from the inside is not recommended and where it is proposed, further testing will be required. Nonload- bearing secondary bonded glazing, e.g. glazing to improve thermal insulation, is not required to comply with the requirements of this sub-Section.

7.16.2 The adhesive is to be flexible enough to support the glazing without holding it firm. The glue strip is to be elastic, with width and thickness designed to allow the glazing to move in both directions in the plane of the glazing without undue forces on the bonding or the substrate. The glass is to be free to settle under load and not be forced to follow deflections in the supporting structure. If substantial racking of the glazing opening under load is expected, the bonding is to be designed to accommodate such deflections.

7.16.3 Bonded windows and side scuttles may be considered as acceptable, in general, on yachts, depending on their position, size of yacht and applicable statutory requirements, noting the distinction between glazing and the frame, which may have different requirements.

7.16.4 Bonded windows and side scuttles are not permitted in galley areas, including glazing in galley doors (internal or external). They are not permitted on escape routes and evacuation routes where a fire rating is required. The fire integrity of bulkheads is not to be impaired.

7.16.5 The failure of laminated glass is considered to pose a lower risk to safety than that of single pane glass. In the event of breaking, laminated glass more readily holds together and tends not to break up into large sharp pieces. Therefore, in general, laminated glazing is preferred. When laminated glass is used, the sealant is to be compatible with the interlayer. Lamination thickness is to be in accordance with *Pt 3, Ch 4, 7.9 Laminated glass thickness 7.9.1*. Special consideration will be given to single pane toughened safety glass.

7.16.6 The durability of the adhesive and the sealant in the long-term marine environment is to be considered in the approval process. Adhesive is to be approved in accordance with *Ch 14, 2.15 Adhesive and sealant materials*. The adhesive bead is to be resistant to or protected from UV radiation, either by an optically dense area at the edges of the glazing or by overlapping trim or UV shielding tape. The adhesive bead is to be resistant to or protected from fungal attack. Arrangements are to be in accordance with the adhesive manufacturer’s published guidelines and relevant LR Rules.

7.16.7 The edges of the bonding recess are to be rounded to facilitate the application of the sealant without air entrapment. The width of the gap between the flange and the glazing is to be large enough to accommodate the movement of the glazing as a result of hull deflection and thermal expansion, *see Figure 4.7.2 Gap width between flange and window, bonded from the outside of the ship*. Recommended gap widths for bonded windows are to be taken as:

Gap width	Length of longest side of window
10–15 mm	< 1,5 m
15–20 mm	1,5–3,0 m

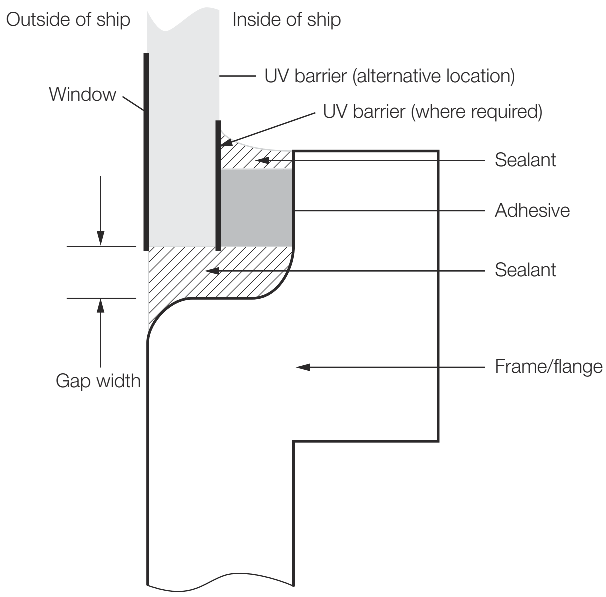


Figure 4.7.2 Gap width between flange and window, bonded from the outside of the ship

7.16.8 The minimum adhesive width and thickness are to be in accordance with the adhesive manufacturer's published guidelines.

■ *Section 8*
Bulwarks, guard rails and other means for the protection of crew

8.1 General

8.1.1 Bulwarks or guard rails are to be provided at the boundaries of exposed freeboard and superstructure decks and first tier deckhouses. Bulwarks or guard rails are to be not less than 1,0 m in height measured above sheathing, and are to be constructed as required by *Pt 3, Ch 4, 8.2 Bulwark construction* and *Pt 3, Ch 4, 8.4 Guard rails* respectively. Special consideration will be given to cases where this height would interfere with the normal operation of the craft.

8.1.2 The freeing arrangements in bulwarks are to be in accordance with *Pt 3, Ch 4, 9 Deck drainage*.

8.1.3 Where appropriate, special consideration will be given to the provision of guard-wires in lieu of bulwarks or guard rails.

8.1.4 Where wire ropes are fitted, adequate devices are to be provided to ensure their tautness.

8.1.5 Where stanchions are fitted, every third stanchion is to be supported by a bracket or stay.

8.1.6 A proper step arrangement is to be provided in way of obstructions such as pipe lines, etc.

8.2 Bulwark construction

8.2.1 Plate bulwarks are to be stiffened by a strong rail section and supported by stays from the deck. The spacing of these bulwark stays is not to be greater than 1,83 m. Where bulwarks are cut to form a gangway or other opening, stays of increased strength are to be fitted at the ends of the openings. Bulwarks are to be adequately strengthened in way of eyeplates for cargo gear, and in way of mooring pipes the plating is to be doubled or increased in thickness and adequately stiffened.

8.2.2 In the calculation of the section modulus, only the material connected to the deck is to be included. The bulb or flange of the stay may be taken into account where connected to the deck, and where, at the ends of the craft, the bulwark plating is connected to the sheerstrake, a width of plating not exceeding that considered effective (*see Pt 6, Ch 3, 1.10 Effective width of*

attached plating, *Pt 7, Ch 3, 1.11 Effective width of attached plating* and *Pt 8, Ch 3, 1.7 Effective width of attached plating* for steel, aluminium alloy and composite construction respectively) may also be included. The free edge of the stay is to be stiffened.

8.2.3 Bulwark stays are to be supported by, or to be in line with, suitable underdeck stiffening, which is to be connected by double continuous fillet welds in way of the bulwark stay connection.

8.2.4 The foregoing requirements do not allow for any loading from deck cargoes.

8.3 Openings in bulwarks

8.3.1 Bulwarks are not to be cut for gangway or other openings near the breaks of superstructures, and are also to be arranged to ensure their freedom from main structural stresses. *See* shell plating in appropriate Chapters.

8.4 Guard rails

8.4.1 The opening below the lowest course of guardrails is not to exceed 230 mm. The other courses are to be spaced not more than 380 mm apart. In the case of craft with rounded gunwales, the guard rail supports are to be placed on the flat of the deck.

8.4.2 Satisfactory means, in the form of guard rails, life-lines, handrails, gangways, underdeck passageways or other equivalent arrangements, are to be provided for the protection of the crew in getting to and from their quarters, the machinery space and all other parts used in the necessary work of the craft.

8.4.3 Chains are only permitted in short lengths in way of access openings.

8.4.4 Where permitted by the National Authority, gangways or walkways may be omitted on craft operating within **Service Groups G1** or **G2**. However, lifelines are to be provided on flush deck craft, or where the cargo hatch coamings are less than 600 mm high.

■ *Section 9*
Deck drainage

9.1 General

9.1.1 Where bulwarks on the weather portions of freeboard or superstructure decks form wells, ample provision is to be made for rapidly freeing the decks of large quantities of water by means of freeing ports, and also for draining them.

9.2 Freeing port area

9.2.1 The minimum freeing area on each side of the craft for each well on the freeboard deck or raised quarter deck, where the sheer in the well is not less than the standard sheer required by the *International Convention on Load Lines*, 1966, is to be derived from the following formulae:

(a) where the length, l , of the bulwark in the well is 20 m or less:

area required = $0{,}7 + 0{,}035\, l$ m^2

(b) where the length, l , exceeds 20 m

area required = $0{,}07\, l$ m^2

l need not be taken greater than $0{,}7L_{\text{L}}$, where L_{L} is the length of the craft as defined in *Pt 3, Ch 1, 6.2 Principal particulars*.

9.2.2 If the average height of the bulwark exceeds 1,2 m or is less than 0,9 m, the freeing area is to be increased or decreased, respectively, by 0,004 m^2 per metre of length of well for each 0,1 m increase or decrease in height respectively.

9.2.3 The minimum freeing area for each well on a first tier superstructure is to be half the area calculated from *Pt 3, Ch 4, 9.2 Freeing port area 9.2.1*.

9.2.4 Two-thirds of the freeing port area required is to be provided in the half of the well nearest to the lowest point of the sheer curve.

9.2.5 When the deck has no sheer, the minimum freeing area for each well calculated from *Pt 3, Ch 4, 9.2 Freeing port area 9.2.1* is to be increased by 50 per cent. Where the sheer is less than the standard the percentage shall be obtained by linear interpolation. The freeing area is to be spread along the length of the well.

9.2.6 Where the length of the well is less than 10 m, or where a deckhouse occupies most of the length, the freeing port area will be specially considered but in general need not exceed ten per cent of the bulwark area.

9.2.7 Where it is not practical to provide sufficient freeing port area in the bulwark, particularly in small craft, credit can be given for bollard and fairlead openings where these extend to the deck.

9.2.8 Where a craft fitted with bulwarks has a continuous trunk, or hatch side coamings that are continuous, or substantially continuous, the minimum freeing area is to be not less than 20 per cent of the total bulwark area where the width of trunk or hatchway is 0,4*B* or less, and not less than 10 per cent of the total bulwark area when the width of the trunk or hatch is 0,75*B* or greater. The freeing area required for an intermediate width of trunk or hatch is to be obtained by linear interpolation.

9.2.9 Where the trunk referred to in *Pt 3, Ch 4, 9.2 Freeing port area 9.2.8* or its equivalent is included in the calculation of freeboard, open rails are to be fitted for at least 50 per cent of the length of the exposed part of the weather deck. Alternatively, if a continuous bulwark is fitted, the minimum freeing area is to be at least 33 per cent of the bulwark area. The freeing area is to be placed in the lower part of the bulwark.

9.2.10 Where a deckhouse has a breadth less than 80 per cent of the beam of the craft, or the width of the side passageways exceed 1,5 m, the arrangement is considered as one well. Where a deckhouse has a breadth equal to or greater than 80 per cent of the beam of the craft, or the width of the side passageways does not exceed 1,5 m, or when a screen bulkhead is fitted across the full breadth of the craft, this arrangement is considered as two wells, before and abaft the deckhouse.

9.2.11 Adequate provision is to be made for freeing water from superstructures which are open at either or both ends and from all other decks within open or partially open spaces in which water may be shipped and contained.

9.2.12 Suitable provision is also to be made for the rapid freeing of water from recesses formed by superstructures, deckhouses and deck cargo arrangements, etc. in which water may be shipped and trapped. Deck gear, particularly on fishing craft, is not to be stowed in such a manner as to obstruct unduly the flow of water to freeing ports.

9.2.13 The lower edges of freeing ports are to be as near to the deck as practicable, and should not be more than 100 mm above the deck.

9.3 Free flow area

9.3.1 The effectiveness of the freeing port area in bulwarks of craft not fitted with a continuous deck obstruction, depends on the free flow across the deck.

9.3.2 The free flow area is the net total longitudinal area of the transverse passageways or gaps between hatchways and superstructures or deckhouses, due account being made for any obstructions such as equipment or other fittings. The height of passageways or gaps used in the calculation of the area is the height of the bulwark.

9.3.3 The provision of freeing area in bulwarks is to be related to the net free flow area as follows:

(a) If the free flow area is equal to, or greater than the freeing port area calculated from *Pt 3, Ch 4, 9.2 Freeing port area 9.2.8* when the hatchway coamings are continuous, then the minimum freeing area calculated from *Pt 3, Ch 4, 9.2 Freeing port area 9.2.1* is sufficient.

(b) If the free flow area is less than the freeing port area calculated from *Pt 3, Ch 4, 9.2 Freeing port area 9.2.1*, then the minimum freeing area is to be that calculated from *Pt 3, Ch 4, 9.2 Freeing port area 9.2.8*.

(c) If the free flow area is less than the freeing port area derived from (a) but greater than that derived from (b), the minimum freeing area, *F*, in the bulwark is to be obtained from the following formula:

$$F = F_1 + F_2 - f_p \text{ m}^2$$

where

F_1 = minimum area from *Pt 3, Ch 4, 9.2 Freeing port area 9.2.1*

F_2 = minimum area from *Pt 3, Ch 4, 9.2 Freeing port area 9.2.8*

f_p = total net area of passages and gaps between hatchways, superstructures and deckhouses (the free flow area)

9.4 Scupper arrangements

9.4.1 Scuppers, sufficient in number and size to provide effective drainage, are to be fitted in all decks.

9.4.2 Scuppers draining weather decks and spaces within superstructures or deckhouses not fitted with efficient weathertight doors are to be led overboard.

9.4.3 Scuppers and discharges which drain spaces below the freeboard deck, or spaces within intact superstructures or deckhouses on the freeboard deck fitted with efficient weathertight doors, may be led to the bilges in the case of scuppers, or to suitable sanitary tanks in the case of sanitary discharges. Alternatively, they may be led overboard provided that:

(a) the freeboard is such that the deck edge is not immersed when the craft heels to 5^{o}, and
(b) the scuppers are fitted with a positive control valve or automatic non-return valve at the shell preventing water from passing inboard.

9.4.4 In craft where an approved fixed pressure water spray fire-extinguishing system is fitted in vehicle or cargo spaces, deck scuppers of not less than 150 mm diameter are to be provided port and starboard, spaced about 9,0 m apart. The scupper area will require to be increased if the design capacity of the drencher system exceeds the Rule required capacity by 10 per cent or more. After installation, the two adjacent sections with the greatest aggregate drencher capacity are to be tested in operation to ensure that there is no build-up of water on the deck. The scuppers are to be led inboard to tanks or, alternatively they may be led overboard providing they comply with *Pt 3, Ch 4, 9.4 Scupper arrangements 9.4.3* and *Pt 3, Ch 4, 9.4 Scupper arrangements 9.4.3.(b)*. Inboard draining scuppers do not require valves but are to be led to suitable drain tanks (water contaminated with petrol or other flammable substance is not to be drained to machinery spaces or any other space where a source of ignition may be present) and the capacity of the tanks is to be sufficient to hold approximately 20 minutes of drenching water. The arrangements for emptying these tanks are to be approved and suitable high level alarms provided. The mouth of the scupper is to be protected by bars.

9.4.5 Scupper pipes from the weather decks discharging overboard below or near the waterline are to be provided with an automatic non-return valve at the shell. This valve may be omitted where the piping has a minimum wall thickness of:

- 7,0 mm for pipes of 80 mm external diameter or smaller;
- 10,0 mm for pipes of 180 mm external diameter;

Intermediate minimum thicknesses are to be determined by linear interpolation.

9.4.6 For the use of non-metallic pipe, *see Pt 15, Ch 1, 8 Plastic pipes* and *Pt 15, Ch 1, 15 Requirements for small craft which are not required to comply with the HSC Code*, as applicable.

9.5 Large freeing port openings

9.5.1 Where the height of freeing ports is greater than 230 mm, vertical bars spaced approximately 230 mm apart may be accepted, as an alternative to a horizontal rail, to limit the height of the freeing port. Other equivalent arrangements will be specially considered.

■ *Section 10*
Cabin sole and lining

10.1 General

10.1.1 Cabin soles are to be fitted and secured in such a manner as to provide access to the structure and fittings below.

10.1.2 The cabin fittings and linings against the side of the craft are to be so fitted as to be capable of being removed when necessary. The method of attachment is not to impair the strength of the structural members.

10.1.3 For fire protection requirements for cabin fittings and linings, *see Pt 17 Fire Protection, Detection and Extinction*.

10.2 Removal for access

10.2.1 It is recommended that the cabin fittings and linings against the side of the craft be so fitted as to be capable of being removed when necessary. The method of attachment is not to impair the strength of the structural members.

10.3 Fire aspects

10.3.1 For information and plans required, *see Pt 17 Fire Protection, Detection and Extinction*.

■ *Section 11* **Ventilators**

11.1 General

11.1.1 This Section provides requirements for ventilators and the ventilation of all craft.

11.1.2 The requirements conform, where relevant, with those of the *International Convention on Load Lines, 1966*. Reference is also to be made to any additional requirements of the National Authority of the country in which the craft is to be registered and to the relevant regulations of the *International Convention for the Safety of Life at Sea, 1974* and applicable amendments.

11.1.3 Special care is to be taken in the design and positioning of ventilator openings and coamings, particularly in the region of the forward end of superstructures and other points of high stress. The deck plating in way of the coamings is to be efficiently stiffened.

11.1.4 The scantlings of ventilators exposed to the weather are to be equivalent to those of the adjacent deck or bulkhead. Where the height of the ventilator exceeds that required by *Pt 3, Ch 4, 11.5 Effective coaming heights 11.5.1*, the thickness may be gradually reduced above that height to a minimum which will be specially considered dependent on the material of construction. Ventilators are to be adequately stayed.

11.1.5 Ventilators from deep tanks and tunnels passing through 'tween decks are to have scantlings suitable for withstanding the pressures to which they may be subjected, and are to be made watertight.

11.1.6 For the requirements for fire precautions on cargo and passenger craft, *see Pt 17 Fire Protection, Detection and Extinction*.

11.1.7 Adequate ventilation is to be provided throughout the craft.

11.1.8 For the requirements for yachts, *see also Pt 4 Additional Requirements for Yachts*.

11.2 Accommodation spaces

11.2.1 Accommodation spaces are to be protected from gas or vapour fumes from machinery, exhaust and fuel systems in accordance with *Pt 3, Ch 2, 4.7 Gastight bulkheads*, *see also Pt 17 Fire Protection, Detection and Extinction*.

11.3 Machinery spaces

11.3.1 In addition to the requirements of this Section, a filter coalescer is to be fitted to the machinery space air intakes to remove fine spray where:

- Intakes are fitted in exposed positions on the weather deck; or
- intakes are large; or
- coaming height is reduced; or
- as required by the engine manufacturer.

Special consideration will be given to alternative arrangements for craft operating within **Service Groups G1-G3**, *see also Pt 9 General Requirements for Machinery*.

11.3.2 In general, ventilators necessary to continuously supply the machinery space or the emergency generator room shall have coamings of sufficient height to comply with *Pt 3, Ch 4, 11.4 Closing appliances 11.4.1*, without having to fit weathertight closing appliances.

11.3.3 Where it is not practical to comply with *Pt 3, Ch 4, 11.3 Machinery spaces 11.3.2* due to ship size and arrangement, lesser heights for machinery space and emergency generator room ventilator coamings, fitted with weathertight closing may be permitted by the Administration in combination with other suitable arrangements to ensure an uninterrupted, adequate supply of ventilation to these spaces.

11.3.4 Where closing appliances are fitted as per *Pt 3, Ch 4, 11.3 Machinery spaces 11.3.3* or *Pt 3, Ch 4, 11.4 Closing appliances 11.4.2*, to ventilators serving emergency generator rooms or closable ventilation louvres are used for emergency generator rooms, the following requirements are to be applied in addition to the requirements of *Pt 3, Ch 4, 11.3 Machinery spaces 11.3.3*:

(a) Ventilation louvres and closing appliances may either be hand-operated or power-operated (hydraulic/pneumatic/electric) and are to be operable under a fire condition. Closing appliances, which automatically close in response to exposure to fire products, are not to be fitted on ventilators located at outside boundaries and serving emergency generator rooms.
(b) Hand-operated ventilation louvres and closing appliances are to be kept open during the normal operation of the vessel. Corresponding instruction notices are to be provided at the location where hand operation is provided.
(c) Power-operated ventilation louvres and closing appliances are to open automatically whenever the emergency generator is starting/in operation. Closed ventilation louvres and closing appliances are acceptable during normal operation of the vessel. In the event of power failure, the default position of the ventilation louvres or closing appliances is to be the open position.
(d) Ventilation openings are to be capable of being operated manually from a clearly marked safe position outside the space where the closing operation can be easily confirmed. The louvre status (open/closed) is to be indicated at this position. Such closing is not to be possible from any other remote position.

11.4 Closing appliances

11.4.1 All ventilator openings are to be provided with efficient weathertight closing appliances unless:

(a) The height of the coaming is greater than 4,5 m above the deck at Position 1.
(b) The height of the coaming is greater than 2,3 m above the deck at Position 2.

11.4.2 In order to limit the fire growth potential in every space of the ship, the main inlets and outlets of all ventilation systems shall be capable of being closed from outside the spaces being ventilated. The means of closing shall be easily accessible as well as be prominently and permanently marked and shall indicate whether the inlet or outlet is open or closed. Unless required by *SOLAS, Chapter II-2, Part C*, *Regulation 9 - Containment of fire* or applicable statutory instruments, emergency generator room ventilators need to be fitted with such means of closing, only when the emergency generator room is fitted with a fixed gas fire-fighting system. Battery room ventilators are to be fitted with a means of closing only when:

(a) the battery room does not open directly onto an exposed deck; or
(b) the ventilation opening for the battery room is required to be fitted with a closing device according to the Load Line Convention; or
(c) the battery room is fitted with a fixed gas fire-extinguishing system.

Where a battery room ventilator is fitted with a closing device, *see Pt 16, Ch 2, 11.5 Construction 11.5.2*. The means of closing mentioned in this paragraph refers to closing appliances of ventilation inlets and outlets for minimising the potential fire growth. The requirements specified are distinct from those for weathertight closing appliances.

11.4.3 Closing appliances are to be permanently attached to the ventilator coaming.

11.4.4 Where, in ferries, ventilators are proposed to be led overboard in an enclosed 'tween deck, the closing arrangements are to be submitted for approval. If such ventilators are led overboard more than 4,5 m above the main vehicle deck, closing appliances may be omitted, provided that satisfactory baffles and drainage arrangements are provided, as in the case of air intakes or exhaust openings for machinery spaces, which may be arranged in the sides of the craft.

11.4.5 Mushroom ventilators closed by a head revolving on a centre spindle (screw down head) are acceptable in Position 2, and also in sheltered positions in Position 1, but the diameter is not to exceed 300 mm if situated within the forward $0{,}25L_L$.

11.4.6 Mushroom ventilators with a fixed head and closed by a screw down plate (screw down cover) may be accepted in exposed positions within the forward $0{,}25L_L$ up to a diameter of 750 mm.

11.4.7 Wall ventilators (jalousies) may be accepted provided they are capable of being closed weathertight by hinged gasketed covers secured by bolts or toggles. They are preferably to face aft or athwartships and are to be fitted with a suitable means of preventing ingress of water and spray when open in the form of louvres, baffles, screens or an equivalent arrangement.

11.4.8 Reference is to be made to *Pt 3, Ch 4, 1 General* concerning down flooding through ventilators which do not require closing appliances due to their coaming height being in accordance with *Pt 3, Ch 4, 11.4 Closing appliances 11.4.1*.

11.5 Effective coaming heights

11.5.1 The height of ventilator coamings exposed to the weather is to be as high as practicable, with a minimum height of 600 mm in Position 1 and 450 mm in Position 2. In particularly exposed positions, the height of coamings may be required to be increased or self closing devices may be required.

11.5.2 Reduced coaming heights may be considered for ventilators which are not required for the operation of the craft at sea, provided that operational procedures are in place and a notice is fitted to the ventilator to ensure that the closing device is closed whilst the craft is at sea.

11.5.3 For gooseneck ventilators, the coaming height is to be measured to the underside of the bend, this being the lowest point through which water on deck could pass freely to spaces below.

11.5.4 Where wall ventilators are fitted with an internal baffle which rises above the lower edge of the exterior opening, the coaming height is measured to the top of the baffle.

11.6 Drainage arrangements

11.6.1 Ventilators are to be provided with suitable drainage arrangements, particularly where an internal baffle is fitted, *see Pt 3, Ch 4, 11.5 Effective coaming heights 11.5.4*.

■ *Section 12*
Air and sounding pipes

12.1 General

12.1.1 Air and sounding pipes are to comply with the requirements of *Pt 15, Ch 2, 11 Air, overflow and sounding pipes*.

12.1.2 The minimum wall thickness of steel and aluminium alloy air pipes in positions indicated in *Pt 3, Ch 4, 12.2 Height of air pipes 12.2.1* is to be taken as:

$$t_p = 0{,}03\, d_p + 3{,}6 \text{ mm with a maximum of } 8{,}5 \text{ mm}$$

where

t_p = wall thickness of air pipe, in mm

d_p = external diameter of air pipe, in mm

12.1.3 The pipe material is to be compatible with the craft construction material.

12.1.4 Striking plates of suitable thickness, or their equivalent, are to be fitted under all sounding pipes.

12.1.5 For the requirements for yachts, *see also Pt 4 Additional Requirements for Yachts*.

12.2 Height of air pipes

12.2.1 The height of air pipes from the upper surface of decks exposed to the weather, to the point where water may have access below is normally to be not less than:

- 450 mm on the freeboard deck;
- 300 mm on the superstructure deck;
- these heights being measured above deck sheathing, where fitted.

12.2.2 Lower heights may be approved in cases where these are essential for the working of the craft, provided that the design and arrangements are otherwise satisfactory.

12.2.3 An increase in the height of air pipes may be required or recommended by individual Administrations when air pipes to fuel oil and settling tanks are situated in positions where sea water could be temporarily entrapped, e.g. in recesses in the sides and ends of superstructures or deckhouses, between hatch ends, behind high sections of bulwark, etc. This may entail an increase in tank scantlings and will be specially considered.

12.2.4 Air pipes are generally to be led to an exposed deck. Alternatively, air pipes from cofferdams or void spaces may terminate in the enclosed 'tween deck space on main vehicle decks, provided the space is adequately ventilated and the air pipes are provided with weathertight closing appliances.

12.2.5 Where air pipes are led through the side of superstructures, the opening is to be at least 2,3 m above the summer load waterline.

12.3 Closing appliances

12.3.1 All openings of air and sounding pipes are to be provided with permanently attached, satisfactory means of closing to prevent the free entry of water (*see also Pt 3, Ch 4, 12.2 Height of air pipes 12.2.2*).

12.3.2 Exposed air pipes in positions 1 and 2 are to be provided with approved automatic closing appliances.

■ *Section 13*
Particular requirements for multi-hull craft

13.1 General

13.1.1 In addition to the general requirements given in this Chapter, this Section gives particular requirements for multi-hull craft.

13.2 Multi-hull craft escape hatches

13.2.1 Multi-hull craft are to be provided with a suitable means of escape from each accommodation compartment between watertight bulkheads in the event of inversion of the craft.

13.2.2 Where the requirement given in *Pt 3, Ch 4, 13.2 Multi-hull craft escape hatches 13.2.1* is achieved by means of escape hatches in the hull, these are to be fitted in the inboard side of each hull, or in the transom, with the lowest side of the opening at a minimum of 600 mm above the waterline in both the upright and inverted conditions of the craft. Hatch openings are to be a minimum of 450 mm x 450 mm and a maximum of 600 mm x 600 mm.

13.2.3 Escape hatch frames and covers may be of steel, aluminium alloy or FRP construction and are to be of equivalent strength to the unpierced hull side or transom in which they are fitted.

13.2.4 Hatch covers are to be weathertight when closed and the means of securing the hatch cover are to be such that weathertightness can be maintained in any sea condition.

13.2.5 Hydrostatic pressure tests are to be carried out to confirm that the proposed construction, when fitted in the hull, is able to withstand a pressure of four times the design pressure and remain watertight.

13.2.6 Hatch covers are to be flush with the hull and substantially hinged. Where fitted in the inboard side of the hull, the hinges are to be on the forward side.

13.2.7 To facilitate a swift and safe means of escape to the lifeboat and life raft embarkation deck, the following provisions apply to overhead hatches fitted along the escape routes addressed by *Regulation 13 - Means of escape*:

(a) escape hatches and their securing devices are to be of a type which can be opened from both sides;
(b) the maximum force needed to open the hatch cover is not to exceed 150 N; and
(c) the use of a spring counterbalance, equalising or any other suitable device on the hinge side to reduce the force needed for opening is acceptable.

13.3 Portlights

13.3.1 Where it is proposed to fit portlights in the hulls of wave-piercing and other non-conventional multi-hull craft, the arrangements will be specially considered.

■ Section 1 General

1.1 Application

1.1.1 The anchoring equipment specified in this Section is suitable only for use in reasonably sheltered conditions or in emergencies. If the equipment is intended to be used during operations in the open sea, or if the sea or weather conditions in the service area are subject to unusual hazards, e.g. typhoons, etc. the equipment will be specially considered in each case.

1.1.2 Where the Equipment Number exceeds 1140 the equipment is to be in accordance with *Pt 3, Ch 13 Ship Control Systems* of the *Rules and Regulations for the Classification of Ships*.

1.2 Definitions

1.2.1 The definitions for use throughout this Chapter are as indicated in the appropriate Section.

1.3 Symbols

1.3.1 The following symbols are used in this Chapter, unless otherwise stated:

b_i = mean breadth of deckhouse or superstructure tier, in metres

h_i = mean height of deckhouse or superstructure tier, in metres

A = area, in m^2, in profile view of the hull, superstructure and deckhouses above the design waterline. Deckhouses with breadth less than $B/4$ are to be ignored

B_0 = the greatest moulded breadth, in metres, or for craft of composite construction, the extreme breadth excluding rubbing strakes or other projections

B_1 = the greatest breadth of the outer hulls of a multi-hull craft, in metres. It is to be measured between the points of intersection of the extension of the hull sides to the normal line of the wet deck

B_2 = the greatest breadth of the centre hull in trimaran type craft, in metres. It is to be measured between the points of intersection of the extension of the hull sides to the normal line of the wet deck

D_h = the sum of $b_i h_i \cos\theta_i$ for all deckhouses and superstructures tiers

G_A = air gap, as defined in *Pt 5, Ch 1 General*

α_1 = for **multi-hull** craft is the distance in metres, from the underside of the cross-deck structure to the underside of the first tier of deckhouse or superstructure

for **mono-hull** craft is the distance in metres, from the waterline to the underside of the first tier of deckhouse or superstructure

θ_i = angle of inclination aft, of tier of deckhouse front, with a line perpendicular to the static load waterline

Δ = loaded displacement, in tonnes

1.4 Character of classification

1.4.1 To entitle a craft to the figure **1** in its character of classification, equipment in accordance with the requirements of this Chapter is to be provided. The regulations governing assignment of the character figure **1** for equipment are given in *Pt 1, Ch 2, 3 Character of classification and class notations*.

1.4.2 For craft intended to be operated only in suitable areas or conditions which have been agreed by LR, as defined in *Pt 1, Ch 2, 3.5 Service area restriction notations*, equipment differing from these requirements may be approved if considered suitable for the particular service on which the craft is to be engaged.

1.4.3 Where the Committee has agreed that anchoring and mooring equipment need not be fitted in view of the particular service of the ship, the character letter **N** will be assigned, *see also Pt 1, Ch 2, 3.2 Character symbols 3.2.2*.

1.4.4 Where the ship is intended to perform its primary designed service function only while it is anchored, moored, towed or linked, the character letter **T** will be assigned, *see also Pt 1, Ch 2, 3.2 Character symbols 3.2.2*.

1.4.5 For classification purposes the character figure **1**, or either of the character letters **N** or **T**, are to be assigned.

■ *Section 2* Equipment Number

2.1 Equipment Number

2.1.1 The anchoring and mooring equipment is based on an Equipment Number, *EN*, which is to be calculated as given in *Pt 3, Ch 5, 2.1 Equipment Number 2.1.2*.

2.1.2 **Mono-hull craft**

$$EN = \Delta^{2/3} + 2(D_h + B_o\,\alpha_1) + 0,1A$$

2.1.3 **Catamaran, Swath, SES and other twin hull craft**

$$EN = \Delta^{2/3} + 2(D_h + B_o\,\alpha_1 + 2G_a B_1) + 0,1A$$

2.1.4 **Trimarans**

$$EN = \Delta^{2/3} + 2(D_h + B_o\,\alpha_1 + G_a(2B_1 + B_2)) + 0,1A$$

2.2 Novel craft

2.2.1 Where a craft is of unusual form and proportions the requirement for equipment will be individually considered on the basis of the Rules.

Section 3
Service group factors

3.1 General

3.1.1 The masses of anchors and the diameters and lengths of chain cable required by *Table 5.5.1 Anchors* and *Table 5.6.1 Chain cable* respectively are for craft in **Service Group G4**.

3.2 Craft in service groups Zone 1 to Zone 3

3.2.1 For craft in service groups **Zone 1** to **Zone 3**, the number and mass of anchors are to comply with *Pt 3, Ch 5, 5.9 Anchors for vessels in service groups Zone 1 to Zone 3*; the strength and length of chain cables are to comply with *Pt 3, Ch 5, 6.9 Anchor chains and wire cables for vessels in service groups Zone 1 to Zone 3*.

3.3 G1 craft

3.3.1 For craft in **Service Group G1**, the equipment is generally to be that required for craft in **Service Group G2**; proposals for further reductions will be specially considered.

3.4 G2, G3, G2A and G4 craft

3.4.1 For craft in **Service Groups G2, G2A, G3**, and **G4**, the mass of the anchor required by *Table 5.5.1 Anchors* may be multiplied by the following factors:

Service Group G2	0,60
Service Group G2A	0,65
Service Group G3	0,73
Service Group G4	1,00

3.4.2 The length and diameter of chain cable are to be those required by *Table 5.6.1 Chain cable* corresponding to the reduced anchor mass given in *Table 5.5.1 Anchors*.

3.4.3 Towlines and mooring lines are to be those required by *Table 5.7.1 Towlines and mooring lines* corresponding to the equipment number as determined from *Pt 3, Ch 5, 2 Equipment Number*.

3.4.4 For service craft on particular duties, a further reduction in the mass of the anchor may be given in accordance with *Pt 3, Ch 5, 4 Craft type factors*.

3.5 G5 craft

3.5.1 Craft in **Service Group G5** are considered for the purposes of this Chapter to be unrestricted in their service, and the equipment is to be in accordance with *Pt 3, Ch 13 Ship Control Systems* of the *Rules for Ships*.

3.6 G6 craft

3.6.1 **Service Group G6** covers yachts and patrol craft having unrestricted service.

3.6.2 For yachts, the mass of the anchors required by *Table 5.5.1 Anchors* may be multiplied by the craft type factor indicated in *Pt 3, Ch 5, 4 Craft type factors*. The length and diameter of chain cable are to be those required by *Table 5.6.1 Chain cable* corresponding to the reduced anchor mass given in *Pt 3, Ch 5, 4 Craft type factors*.

3.6.3 For patrol craft, the equipment is to be in accordance with *Pt 3, Ch 13 Ship Control Systems* of the Rules for Ships for unrestricted service.

Section 4
Craft type factors

4.1 General

4.1.1 The mass of the anchors required by *Table 5.5.1 Anchors* and corrected for service group factors in accordance with *Pt 3, Ch 5, 3 Service group factors* (where applicable), are to be corrected by the craft type factors indicated in this Section.

4.2 Craft type factors

4.2.1 **Yachts** with an Equipment Numeral, *EN*, of less than or equal to 220 as determined in *Pt 3, Ch 5, 2.1 Equipment Number*, may have the mass of the anchors as required by *Table 5.5.1 Anchors* reduced by the craft type factor, k_y, in accordance with the following:

$$k_y = \frac{EN}{500} + 0,56$$

4.2.2 For yachts with an Equipment Numeral, *EN*, in excess of 220, the craft type factor, k_y, is to be taken as unity.

4.2.3 **Pilot and Patrol** craft operating within **Service Group G1**, and which do not normally anchor in the course of their duties, with an Equipment Numeral *EN* of less than or equal to 220 as determined in *Pt 3, Ch 5, 2.1 Equipment Number*, may have the mass of the anchor as required by *Pt 3, Ch 5, 3 Service group factors* reduced by the craft type factor, k_{p1}, in accordance with the following:

$$k_{p1} = \frac{EN}{980} + 0,28$$

4.2.4 **Pilot and patrol** craft operating within **Service Group G2**, and which do not normally anchor in the course of their duties, with an Equipment Numeral *EN* of less than or equal to 100 as determined in *Pt 3, Ch 5, 2.1 Equipment Number 2.1.2*, may have the mass of the anchor as required by *Pt 3, Ch 5, 3 Service group factors* reduced by the craft type factor, k_{p2}, in accordance with *Table 5.4.1 Craft type factor*.

Table 5.4.1 Craft type factor

Equipment Numeral, *EN*				Craft type factor, k_{p2}
≥	5	≤	40	0,8
>	40	≤	100	0,9
>	100			1,0

Section 5
Anchors

5.1 General

5.1.1 The Rules are based on the use of high holding power (HHP) type anchors.

5.1.2 When ordinary holding power anchors are used as bower anchors, the mass given in *Table 5.5.1 Anchors* is to be increased by 33 per cent.

5.1.3 Where it is proposed to fit other types of anchor, the mass will be specially considered.

5.1.4 Craft other than yachts must have at least a single anchor ready for immediate deployment for any voyage or transit.

5.1.5 **Yachts** are to be provided with two anchors on board. Each anchor must have the rule length of chain cable attached. Only one anchor is required to be ready for immediate deployment, i.e. around the capstan. The masses of anchors may be of the following combinations:

(a) The mass of the first anchor is to be not less than 100 per cent of the Rule value for the type of anchor concerned. The mass of the second anchor is to be not less than 70 per cent of the Rule value for the type concerned.

(b) The mass of each anchor is to be not less than 90 per cent of the Rule value for the type of anchor concerned.

5.1.6 The fitting of a single anchor on board yachts will be specially considered. The mass of the single anchor is to be not less than 100 per cent of the Rule value for the type of anchor concerned.

5.1.7 Anchors which must be specially laid the right way up, or which require the fluke angle or profile to be adjusted for varying types of sea bed, will not generally be approved for normal craft use. In such cases suitable tests may be required.

5.1.8 Anchors are to be of an approved design. The design of all anchor heads is to be such as to minimise stress concentrations, and in particular, the radii on all parts of cast anchor heads are to be as large as possible, especially where there is considerable change of section.

5.2 Materials

5.2.1 The requirements for anchor materials are contained in the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

5.2.2 Anchors made of stainless steels or aluminium alloy may be acceptable subject to special consideration.

5.2.3 Where aluminium alloy anchors are proposed, due consideration is to be given to the compatibility of such anchors with the materials of the chain cable, anchor shackle, etc. in order to avoid galvanic corrosion.

Table 5.5.1 Anchors

Equipment number		High holding power bower anchors	
Exceeding	Not exceeding	Number of anchors	Mass of anchor, in kg
-	5	1	11
5	10	1	13
10	15	1	17
15	20	1	22
20	25	1	27
25	30	1	32
30	35	1	37
35	40	1	44
40	45	1	52
45	50	1	59
50	70	1	80
70	90	1	117
90	110	1	154
110	130	1	197
130	150	1	240
150	175	1	292
175	205	1	360
205	240	1	428

240	280	1	495
280	320	1	585
320	360	1	675
360	400	1	765
400	450	1	855
450	500	1	968
500	550	1	1080
550	600	1	1193
600	660	1	1305
660	720	1	1440
720	780	1	1575
780	840	1	1710
840	910	1	1845
910	980	1	1980
980	1060	1	2138
1060	1140	1	2295

5.3 Testing

5.3.1 Testing of anchors is to be carried out in accordance with *Ch 10 Equipment for Mooring and Anchoring* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2021*.

5.3.2 For holding power testing requirements relating to high holding power anchors, *see Ch 10, 1.3 Anchor holding power tests for HHP and SHHP anchors* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2021*.

5.4 Anchor shackle

5.4.1 Steel anchor shackles are to be forged or cast steel of approved manufacturer.

5.5 Anchor stowage

5.5.1 Anchors are generally to be housed in suitable hawse pipes, or stowed in dedicated chocks on deck.

5.5.2 Hawse pipes and anchor pockets are to be in accordance with *Pt 3, Ch 5, 9.2 Hawse pipes and anchor recesses*. Alternatively, roller fairleads of suitable design may be fitted. Where hawse pipes are not fitted, alternative arrangements will be specially considered.

5.5.3 It is recommended that anchor lashings, e.g. a ‘devil’s claw’, be fitted to hold the anchor tight against the hull or the anchor pocket. Anchor lashings are to be designed to resist at least a load corresponding to twice the anchor mass plus 10 m of cable without exceeding 40 per cent of the yield strength of the material.

5.6 Super high holding power (SHHP) type anchors

5.6.1 In craft where the HHP anchor mass given in *Table 5.5.1 Anchors* does not exceed 2295 kg, the use of SHHP type anchors of reduced mass will be specially considered. However, the reduced SHHP anchor mass is not to be less than 67 per cent of that specified for HHP anchors in *Table 5.5.1 Anchors*.

5.6.2 Final acceptance will be dependent upon satisfactory strength and performance tests.

5.6.3 Anchors of designs for which approval is sought as super high holding power anchors are to be tested at sea to show that they have holding powers of at least four times those of approved standard stockless anchors of the same mass. For holding

power testing requirements relating to SHHP anchors, *see Ch 10, 1.3 Anchor holding power tests for HHP and SHHP anchors* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2021*.

5.7 Tolerances

5.7.1 The mass of each high holding power anchor given in *Table 5.5.1 Anchors* is for anchors of equal mass. The masses of individual anchors may vary by ± 7 per cent of the masses given in the Table, provided that the total mass of the anchors is not less than would have been required for anchors of equal mass.

5.8 Identification

5.8.1 Identification of anchors which have been tested is to be in accordance with *Ch 10, 1.5 Forged steel anchors*of the Rules for Materials.

5.9 Anchors for vessels in service groups Zone 1 to Zone 3

5.9.1 For passenger vessels and vessels not intended for the carriage of goods, the total mass *P*, in kg, of the bow anchor(s) is to be as prescribed by the National Authority for the intended service.

5.9.2 In the absence of specified criteria from the National Authority, the mass of high holding power anchors shall be determined as in *Pt 3, Ch 5, 5.9 Anchors for vessels in service groups Zone 1 to Zone 3 5.9.3*, and the mass of ordinary stockless bower anchors can be determined as in *Pt 3, Ch 5, 5.9 Anchors for vessels in service groups Zone 1 to Zone 3 5.9.4*.

5.9.3 Where the required mass for anchors of a design approved for the designation ‘High Holding Power’ (HHP) or ‘Super High Holding Power’ (SHHP) is used, the mass of each such anchor will be specially considered on the basis of the vessel’s characteristics and the characteristics of winds, waves and current in the proposed operation area.

5.9.4 For ordinary stockless bower anchors and in the absence of relevant criteria by the National Authorities, the mass of ordinary stockless bower anchors can be calculated in accordance with the criteria given in the *Rules and Regulations for the Classification of Inland Waterways Ships, July 2021*, *Pt 3, Ch 12, 5 Equipment*.

■ *Section 6* Anchor cable

6.1 General

6.1.1 Anchor cable may be of stud link chain, short link chain, wire rope or fibre rope, subject to the requirements of this Section.

6.1.2 An easy lead of the cables from the windlass to the anchors and chain lockers is to be arranged.

6.1.3 For each anchor required to be carried on board, *see Pt 3, Ch 5, 5.1 General 5.1.5*, a length of anchor cable, as indicated in *Table 5.6.1 Chain cable*, is to be provided.

6.2 Chain cable

6.2.1 The diameter of stud link chain cable is to be as indicated in *Table 5.6.1 Chain cable*.

6.2.2 Short link chain cable may be accepted provided that the breaking load is not less than that of stud link chain cable of the diameter required by *Table 5.6.1 Chain cable*.

6.2.3 Chain cables may be of mild steel, special quality steel or extra quality steel in accordance with the requirements of *Ch 10 Equipment for Mooring and Anchoring* of the Rules for Materials, and are to be graded in accordance with *Table 5.6.2 Grades of steel for use as chain cable*.

6.2.4 Grade U1 material having a tensile strength of less than 400 N/mm^2 is not to be used in association with high holding power anchors. Grade U3 material is to be used only for chain 20,5 mm or more in diameter.

6.2.5 In addition to *Pt 3, Ch 5, 6.2 Chain cable 6.2.3* special consideration will be given to the use of chain cable of stainless steel. Stainless steel is to be of a suitable type, details of which are to be submitted for consideration.

6.2.6 The form and proportion of links and shackles are to be in accordance with *Ch 10 Equipment for Mooring and Anchoring* of the Rules for Materials.

Table 5.6.1 Chain cable

Mass of HHP bower anchor, in kg	Length of chain cable, in metres	Stud link chain cable diameter, in mm		
		Mild steel (Grade:1 or U1)	Special quality steel (Grade:U2)	Extra special quality steel (Grade:U3)
11	55	8	-	-
13	55	8	-	-
17	55	8	-	-
22	55	9	-	-
27	55	9	-	-
32	82,5	9	-	-
37	82,5	11,2	-	-
44	82,5	11,2	-	-
52	110	11,2	-	-
59	110	12,5	-	-
			-	-
80	110	12,5	-	-
117	110	14	12,5	-
154	110	16	14	-
197	137,5	17,5	16	-
240	137,5	19	17,5	-
292	137,5	20,5	17,5	-
360	137,5	22	19	-
428	165	24	20,5	-
495	165	26	22	20,5
585	165	28	24	22
675	192,5	30	26	24
765	192,5	32	28	24
855	192,5	34	30	26
968	192,5	36	32	28
1080	220	38	34	30
1193	220	40	34	30
1305	220	42	36	32

1440	220	44	38	34
1575	220	46	40	36
1710	247,5	48	42	36
1845	247,5	50	44	38
1980	247,5	52	46	40
2138	247,5	54	48	42
2295	247,5	56	50	44

Table 5.6.2 Grades of steel for use as chain cable

Grade	Material	Tensile strength (N/mm^2)
U1	Mild steel	300 - 490
U2(a)	Special quality steel (wrought)	490 - 690
U2(b)	Special quality steel (cast)	490 - 690
U3	Extra special quality steel	690 min

6.3 Testing

6.3.1 Chain cable with a diameter of 12,5 mm or above is to be certified by Lloyd's Register (hereinafter referred to as 'LR'). Chain cable with a diameter below 12,5 mm is to be certified by a recognised testing establishment.

6.3.2 All chain cables are to be tested at establishments and on machines recognised by the Committee and under the supervision of LR's Surveyors or other Officers recognised by the Committee, and in accordance with *Ch 10 Equipment for Mooring and Anchoring* of the Rules for Materials.

6.3.3 Test certificates showing particulars of size and weight of cable and of the test loads applied are to be furnished. These certificates are to be examined by the Surveyors when the cables are placed on board the craft.

6.4 Wire rope

6.4.1 When the Equipment Number does not exceed 500 for craft in **Service Groups G1, G2, G2A** and **G3**, steel wire rope may be accepted in lieu of chain cable under the following conditions:

(a) A length of chain of the diameter specified in *Table 5.6.1 Chain cable* is to be fitted to the anchor. The total length of chain is to be not less than 10 per cent of the total required by *Table 5.6.1 Chain cable*. In no case is the length of chain attached to an anchor to be less than 9 metres.
(b) The wire rope used in lieu of chain cable is to have a breaking load of not less than that of the chain cable it replaces.
(c) The combined length of the chain cable specified in (a) and the wire is to be not less than the length of chain cable required by *Table 5.6.1 Chain cable*.
(d) Thimbles are to be fitted at both ends of the wire rope, as appropriate.
(e) Suitable precautions are to be taken to reduce the wear on the wire rope at fairleads, etc.

6.4.2 Steel wire ropes are to be manufactured, tested and certified as required by *Ch 10 Equipment for Mooring and Anchoring* of the Rules for Materials .

6.5 Fibre rope

6.5.1 When the Equipment Number does not exceed 100, polyamide (or other equivalent synthetic fibre) rope may be accepted in lieu of wire rope, subject to compliance with *Pt 3, Ch 5, 6.4 Wire rope 6.4.1*.

6.5.2 Fibre ropes are to be manufactured, tested and certified as required by *Ch 10 Equipment for Mooring and Anchoring* of the Rules for Materials.

6.5.3 Synthetic fibre ropes are to be ultra-violet inhibited as necessary, dependent upon their type.

6.6 Cable clench

6.6.1 Provision is to be made for securing the bitter end of the chain cable to the ship structure. The fastening for securing the bitter end is to be capable of withstanding a force of not less than 15 per cent and not greater than 30 per cent of the minimum breaking strength of the as fitted chain cable. It is to be provided with suitable means such that, in case of emergency, the chain cable may be easily slipped to sea from an accessible position outside the chain cable locker. Where the mechanism for slipping the chain cable to sea penetrates the chain locker bulkhead, this penetration is to be made watertight.

6.6.2 Alternatively the cable end connection may be accepted where it has been designed and constructed to a recognised National or International Standard.

6.6.3 The cable clench supporting structure is to be adequately stiffened in accordance with the breaking strength of the fastening provided.

6.7 Cable stopping and release arrangements

6.7.1 It is recommended that suitable bow chain stoppers be provided. Where cables pass through stoppers, these stoppers are to be manufactured from ductile material and be designed to minimise the possibility of damage to, or snagging of, the cable. They are to be capable of withstanding without permanent deformation a load equal to 80 per cent of the Rule breaking load of the cable passing over them. The corresponding stresses induced in the supporting structure are not to exceed the allowable values given in *Table 5.6.3 Allowable stresses in windlass and chain stopper supporting structure*. The capability of the supporting structure to withstand buckling is also to be assessed. Strength and buckling calculations are to be submitted for consideration.

Table 5.6.3 Allowable stresses in windlass and chain stopper supporting structure

	Permissible stress N/mm^2
Normal stress (*see* Note 1)	$1,00\sigma_0$
Shear stress	$0,58\sigma_0$
Combined stress (*see* Note 2)	$1,00\ \sigma_0$
Symbols	
σ_0= specified minimum yield stress, N/mm^2	
Note 1 Normal stress is defined as the sum of bending and axial stresses.	
Note 2 Combined stress refers to equivalent von Mises stress.	

6.8 Cable locker

6.8.1 Adequate storage is to be provided to accommodate the full length of anchor cable.

6.8.2 The chain locker is to be of a capacity and depth adequate to provide an easy direct lead for the cable into the chain pipes, when the cable is fully stowed. Chain or spurling pipes are to be of suitable size and provided with chafing lips. The port and starboard cables are to be separated by a division in the locker.

6.8.3 Chain lockers and spurling pipes are to be watertight up to the exposed weather deck and the space is to be efficiently drained. However, bulkheads between separate chain lockers, or which form a common boundary of chain lockers, need not be watertight.

6.8.4 Where means of access is provided to the chain locker, it is to be closed by a substantial cover and secured by closely spaced bolts.

6.8.5 Where a means of access to spurling pipes or cable lockers is located below the weather deck, the access cover and its securing arrangements are to be in accordance with ISO 5894-1999, or an equivalent National Standard acceptable to LR, recognised standards or equivalent for watertight manhole covers. Butterfly nuts and/or hinged bolts are prohibited as the securing mechanism for the access cover.

6.8.6 The chain locker is to be provided with adequate drainage facilities.

6.9 Anchor chains and wire cables for vessels in service groups Zone 1 to Zone 3

6.9.1 The length and size of chains and wire cables are to be as prescribed by the National Authority for the intended service.

6.9.2 In the absence of specified criteria from the National Authority, the length and size of chains and wire cables can be calculated in accordance with the criteria given in the *Rules and Regulations for the Classification of Inland Waterways Ships, July 2021*, *Pt 3, Ch 12, 5 Equipment*.

■ *Section 7* Mooring ropes and towlines

7.1 Mooring ropes

7.1.1 Craft under 90 m in length are to be equipped with mooring ropes in accordance with *Table 5.7.1 Towlines and mooring lines*.

7.1.2 The lengths of individual mooring lines in *Table 5.7.1 Towlines and mooring lines* may be reduced by up to seven per cent of the Table length, provided that the total length of mooring lines is not less than would have resulted had all lines been of equal length. Proposals to fit individual mooring lines of reduced length to suit the particular service will be specially considered.

7.2 Materials

7.2.1 Mooring lines may be of steel wire rope, natural fibre or synthetic fibre. The diameter, construction and specification of wire or natural fibre mooring lines are to comply with the requirements of *Ch 10 Equipment for Mooring and Anchoring*of the Rules for Materials . Where it is proposed to use synthetic fibre ropes, the size and construction will be specially considered.

7.3 Testing and certification

7.3.1 Mooring ropes are to be tested and certified in accordance with *Ch 10 Equipment for Mooring and Anchoring* of the Rules for Materials.

7.4 Towlines

7.4.1 Towlines are not required for classification other than for craft which are required to comply with the *IMO Code of Safety for High Speed Craft*. The details given in *Table 5.7.1 Towlines and mooring lines* are for guidance purposes only.

Table 5.7.1 Towlines and mooring lines

Equipment Number		Towline, *See* Notes		Mooring lines		
Exceeding	Not Exceeding	Minimum length, in metres	Minimum breaking strength, in kN	Number of lines	Minimum length of each line, in metres	Minimum breaking strength, in kN
-	5	90	19,9	2	55	13,9
5	10	90	22,5	2	55	17,6
10	15	90	27,7	2	55	21,5

15	20	90	32,9	2	55	24,5
20	25	110	38,1	2	55	26,6
25	30	110	43,3	2	55	28,2
30	35	110	48,5	2	55	29,6
35	40	135	53,7	2	55	30,8
40	45	135	58,9	2	70	31,8
45	50	135	64,1	2	85	32,7
50	70	180	71,0	2	100	35,5
70	90	180	82,1	2	100	39,3
90	110	180	93,2	2	110	43,1
110	130	180	104,3	2	110	46,6
130	150	180	115,3	2	120	50,2
150	175	180	127,8	2	120	54,4
175	205	180	143,0	2	120	58,8
205	240	180	161,1	2	120	64,2
240	280	180	181,8	3	120	71,1
280	320	180	204,0	3	140	78,5
320	360	180	226,1	3	140	85,8
360	400	180	248,3	3	140	93,2
400	450	180	273,2	3	140	100,5
450	500	180	300,9	3	140	107,9
500	550	180	328,6	4	160	112,8
550	600	180	356,3	4	160	117,7
600	660	180	386,8	4	160	122,6
660	720	180	420,1	4	160	127,5
720	780	180	453,3	4	170	132,4
750	840	180	486,5	4	170	137,3
840	910	180	522,5	4	170	142,2
910	980	180	561,3	4	170	147,1
980	1060	180	602,9	4	180	156,9

1060	1140	180	647,2	4	180	166,7

Note 1. Towline specified for guidance only, *see Pt 3, Ch 5, 7.4 Towlines 7.4.1*.

Note 2. Wire ropes used for towlines and mooring lines are generally to be of a flexible construction with not less than:
144 wires in six strands with seven fibre cores for strengths up to 490 kN
222 wires in six strands with one fibre core for strenghths exceeding 490 kN
The wires to be laid around the fibre centre of each strand are to be up in not less than two layers.

Note 3. Wire ropes for towlines and mooring lines used in association with mooring winches (on which the rope is stored on the winch drum) are to be of suitable construction.

Note 4. Irrespective of strength of requirements, no fibre rope is to be less than 12 mm diameter.

7.5 Bollards, fairleads and bull rings

7.5.1 Means are to provided to enable mooring lines to be adequately secured on board the craft. It is recommended that the total number of suitably placed bollards on either side of the craft and/or the total brake holding power of mooring winches should be capable of holding not less than 1,5 times the sum of the maximum breaking strengths of the mooring lines required or recommended. Attention is drawn to the existence of a number of National Standards for bollards and fairleads, and to the importance of ensuring that their seating arrangements, including the supporting hull structure, are efficiently constructed and adequate for the intended loads.

7.6 Towing requirements

7.6.1 Craft which are to comply with the *IMO Code of Safety for High Speed Craft* are to be provided with adequate arrangements to enable the craft to be towed in the worst intended environmental conditions. It is recommended that other craft comply with this requirement.

7.7 Towing bitts

7.7.1 Where towage is to be from more than one point a suitable bridle is to be provided.

7.7.2 Details of the structural scantlings, arrangements, loadings and design assumptions for the towing bitts are to be submitted for consideration.

7.7.3 The towing arrangements should be such that damage to the towline or bridle from abrasion is minimised.

7.8 Mooring winches

7.8.1 Mooring winches where provided are to be suitable for the intended purpose. Supports under the winches are to be to the Surveyor's satisfaction.

7.8.2 Mooring winches are to be fitted with drum brakes, the strength of which is sufficient to prevent unreeling of the mooring line when the rope tension is equal to 80 per cent of the breaking strength of the rope as fitted on the first layer on the winch drum, *see also Pt 3, Ch 5, 7.5 Bollards, fairleads and bull rings 7.5.1*.

■ *Section 8* Anchor windlass design and testing

8.1 General

8.1.1 A windlass, capstan or winch used for handling anchors, suitable for the size of chain cable required by *Pt 3, Ch 5, 6 Anchor cable* and complying with the following criteria is to be fitted. Where Owners require equipment significantly in excess of Rule requirements, it is their responsibility to specify increased windlass power.

8.1.2 The design, construction and testing of windlasses are to conform with a relevant National or International Standard or code of practice acceptable to LR. To be considered acceptable, the standard, or code of practice, is to specify criteria for evaluation of stresses, performance and testing.

8.1.3 Operation and maintenance procedures for the anchor windlass are to be incorporated in the vessel operations manual.

8.1.4 Windlasses may be hand or power operated, subject to the requirements of *Pt 3, Ch 5, 8.4 Windlass design 8.4.3*.

8.1.5 Where steel wire rope is used in lieu of chain cable, a suitable winch with sufficient drum capacity to store the length of wire rope fitted is to be provided.

8.1.6 The windlass, anchoring capstans and winches are to be of types approved by LR.

8.1.7 On craft equipped with anchors having a mass of over 50 kg windlass(es) of sufficient power and suitable for the type and size of chain cable are to be fitted. Arrangements with anchor davits will be specially considered.

8.2 Plans and particulars to be submitted

8.2.1 The following plans showing the design specifications, the standard of compliance, engineering analyses and details of construction, as applicable, are to be submitted for evaluation:

- Windlass design specifications, anchor and chain cable particulars, performance criteria, and standard of compliance.
- Windlass foundation drawings including the supporting structure below deck. The details shall include bolts, chocks, shear stoppers etc., along with the foot print loads for the specified windlass ratings.
- Chain stopper foundation drawings including the of the supporting structure below deck. The details shall include bolts, chocks, shear stoppers etc., along with the foot print loads for the specified rating.
- Windlass arrangement plans showing all the components of the anchoring/mooring system such as the prime mover, shafting, cable lifter, anchors and chain cables; mooring winches, wires and fairleads, if they form part of the windlass machinery, brakes, controls, etc.
- Dimensions, materials, welding details, as applicable, of all torque-transmitting components (shafts, gears, clutches, couplings, coupling bolts, etc.) and all load-bearing components (shaft bearings, cable lifter, sheaves, drums, bed-frames, etc.) of the windlass and of the winch, where applicable, including brakes, chain stopper (if fitted), and foundation.
- Hydraulic system, to include:

(i) piping diagram along with system design pressure;
(ii) safety valves arrangement and settings;
(iii) material specifications for pipes and equipment;
(iv) typical pipe joints, as applicable;
(v) technical data and details for hydraulic motors;
(vi) cooling systems arrangements for hydraulic system oil.

- Electrical one-line diagram along with cable specification and size, motor controller, protective device rating or setting, as applicable.
- Control, monitoring and instrumentation arrangements.
- Engineering analyses for torque-transmitting and load-bearing components demonstrating their compliance with recognised standards or codes of practice. Analyses for gears are to be in accordance with a recognised standard.
- Calculations proving satisfactory inertia loads for the intended windlass, *see Pt 3, Ch 5, 8.4 Windlass design 8.4.1.(b)*.
- Plans and data for windlass electric motors including associated gears rated 100 kW and over.
- Calculations demonstrating that the windlass prime mover is capable of attaining the hoisting speed, the required continuous duty pull, and the overload capacity are to be submitted if the ‘load testing’ including ‘overload’ capacity of the entire windlass unit is not carried out at the shop (*see Pt 3, Ch 5, 8.11 Shop inspection and testing 8.11.1.(b)*).

8.3 Materials and fabrication

8.3.1 Materials used in the construction of torque-transmitting and load-bearing parts of windlasses are to comply with LR's *Rules for the Manufacture, Testing and Certification of Materials, July 2021* or an appropriate National or International Standard acceptable to LR, provided that the Standard gives reasonable equivalence to the requirements of LR. The proposed materials are to be indicated in the construction plans and are to be approved in connection with the design. All such materials are to be certified by the material manufacturers and are to be traceable to the manufacturers’ certificates.

8.3.2 Weld joint designs are to be shown in the submitted construction plans and are to be appraised in association with the approval of the windlass design in accordance with an appropriate National or International Standard acceptable to LR. .

8.3.3 Welding procedures, welding consumables and welders are to comply with the LR *Rules for the Manufacture, Testing and Certification of Materials, July 2021* or an appropriate National or International Standard acceptable to LR.

8.3.4 The degree of non-destructive examination of welds and post-weld heat treatment, if any, are to be specified and submitted for consideration.

8.4 Windlass design

8.4.1 In addition to the requirements of the National or International Standard or code of practice acceptable to LR (*see Pt 3, Ch 5, 8.1 General 8.1.2*) the following performance requirements are to be complied with:

(a) Holding Loads: Calculations are to be made to show that, in the holding condition (single anchor, brake fully applied and chain cable lifter declutched) and under a load equal to 80 per cent of the specified minimum breaking strength of the chain cable, the maximum stress in each load bearing component will not exceed the maximum permissible yield. For installations fitted with a chain cable stopper, 45 per cent of the specified minimum breaking strength of the chain cable may instead be used for the calculation.

(b) Inertia Loads: The design of the drive train, including prime mover, reduction gears, bearings, clutches, shafts, cable lifter and bolting is to consider the dynamic effects of sudden stopping and starting of the prime mover or chain cable, so as to limit inertial load.

(c) Continuous Duty Pull: The windlass is to have sufficient power to exert a continuous duty pull , Z_{cont1}, over a period of 30 minutes corresponding to the grade and diameter, d_c, of the chain cables as follows:

(i) for specified design anchorage depths up to 82,5 m when using ordinary stockless anchors: :

Chain cable grade	Z_{cont1} (N)
U1	$37{,}5 d_c^2$
U2	$42{,}5 d_c^2$
U3	$47{,}5 d_c^2$
unit of d	mm

(ii) for specified design anchorage depths greater than 82,5 m a continuous duty pull Z_{cont2} is:

$$Z_{cont2} = Z_{cont1} + \left(D_a - 82{,}5\right) 0{,}27 d_c^2 \text{N}$$

where

d_c = is the chain diameter, in mm

D_a = is the specified design anchorage depth, in metres

The anchor masses are assumed to be the masses as given in *Table 5.6.1 Chain cable*. The value of Z_{cont} is based on the hoisting of one anchor at a time, assumes that the effects of buoyancy and hawse pipe efficiency (assumed to be 70 per cent) have been accounted for. In general, stresses in each torque-transmitting component are not to exceed 40 per cent of yield strength (or 0,2 per cent proof stress) of the material under these loading conditions.

(d) Overload Capability: The windlass prime mover is to be able to provide, for a period of at least two minutes, the necessary temporary overload capacity for breaking out the anchor. This temporary overload capacity is to be a pull equal to the greater of:

(i) short term pull:

1,5 times the continuous duty pull as defined in *Pt 3, Ch 13, 8.4 Windlass design 8.4.1.(c)*, or

(ii) anchor breakout pull:

$$12{,}18 W_a + \frac{7{,}0 L_c d_c^2}{100} \text{N}$$

where:

L_c = is the total length of chain cable on board, in metres, as given by *Table 5.6.1 Chain cable*

W_a = is the mass of bower anchor(kg) as given in *Table 5.5.1 Anchors*.

Note The speed in this period may be lower than normal.

(e) Hoisting Speed: The mean speed of the chain cable during hoisting of the anchor and cable is to be 0,15 m/s.

(f) Brake Capacity: The capacity of the windlass brake is to be sufficient to stop the anchor and chain cable when paying out the chain cable in a controlled manner. Where a chain cable stopper is not fitted, the brake is to produce a torque capable of withstanding a pull equal to 80 per cent of the specified minimum breaking strength of the chain cable without any permanent

deformation of strength members and without brake slip. Where a chain cable stopper is fitted, 45 per cent of the breaking strength may instead be applied. The following simplified formula is to be used to calculate the required brake capacity:

$K_b d_c^2 (44 - 0{,}08 d_c)$ N

where K_b is given in *Table 5.8.1 Values of K_b* .

Table 5.8.1 Values of K_b

	K_b	
Cable grade	Windlass used in conjunction with chain stopper	Chain stopper not fitted
U1	4,41	7,85
U2	6,18	11,0
U3	8,83	15,7

8.4.2 As an alternative to conducting the engineering analyses required by *Pt 3, Ch 5, 8.4 Windlass design 8.4.1*, approval of the windlass mechanical design can be based on a type test, in which case the testing procedure is to be submitted for consideration.

8.4.3 Calculations for torque transmitting components are to be based on 1500 hours of operation with a nominal load spectrum factor of K_m = 1,0. Alternatively unlimited hours with a nominal load spectrum factor of K_m = 0,8 can be applied.

8.4.4 The following criteria are to be used for gearing design:

(a) Torque is to be based on the performance criteria specified in *Pt 3, Ch 5, 8.4 Windlass design 8.4.1*.
(b) The use of an equivalent torque, T_{eq}, for dynamic strength calculations is acceptable but the derivation is to be submitted to LR for consideration.
(c) The application factor for dynamic strength calculation, K_A, is to be 1,15.
(d) Calculations are to be based on 1500 hours of operation.
(e) The static torque is to be 1,5 x T_n where T_n is the nominal torque.
(f) The minimum factors of safety for load capacity of spur and helical gears, as derived using ISO 6336 or a relevant National or International standard acceptable to LR, are to be 1,5 for bending stress and 0,6 for contact stress.

Gears intended to transmit power greater than 100 kW are to be certified by LR, and the gears are to meet the requirements of *Pt 11, Ch 1 Gearing*.

8.5 Additional requirements for windlass design for Special Service Craft

8.5.1 Hand-operated windlasses are only acceptable if the effort required at the handle does not exceed 150N for raising one anchor at a speed of not less than 2 m/min and making about thirty turns of the handle per minute.

8.5.2 windlasses suitable for operation by hand as well as by external power are to be so constructed that the power drive cannot activate the hand drive.

8.5.3 Where a chain stopper is fitted, the windlass braking system is to have sufficient brake capacity to ensure safe stopping when paying out the anchor and chain. It is the Master's responsibility to ensure that the chain stopper is in use when riding at anchor. At clearly visible locations on the bridge and adjacent to the windlass control position, the following notice is to be displayed adjacent to the windlass control position, and at clearly visible locations on the bridge if the windlass can be operated remotely:

'The brake is rated to permit controlled descent of the anchor and chain only. The chain stopper is to be used at all times whilst riding at anchor.'

8.6 Alternative windlass design requirements for Special Service Craft for restricted service

8.6.1 Where a chain cable of grade U1 with diameter d_c less than 14 mm is used, the windlass is to have sufficient power to exert, over a period of 30 minutes, a continuous duty pull of:

$$Z_{cont1} = 28{,}5 d_c^2$$

In all other cases the windlass is to be capable of providing a continuous duty pull as required by *Pt 3, Ch 5, 8.4 Windlass design 8.4.1.(c)*.

8.6.2 Where *Pt 3, Ch 5, 8.6 Alternative windlass design requirements for Special Service Craft for restricted service 8.6.1* applies, the windlass overload capacity is to meet the requirement of the short-term pull as defined in *Pt 3, Ch 5, 8.4 Windlass design 8.4.1.(d)* using the continuous duty pull defined in *Pt 3, Ch 5, 8.6 Alternative windlass design requirements for Special Service Craft for restricted service 8.6.1*.

8.6.3 All aspects of windlass design except those referenced above are to meet the requirements of *Pt 3, Ch 5, 8.4 Windlass design*.

8.7 Hydraulic systems

8.7.1 Hydraulic systems, where employed for driving windlasses are to comply with the requirements of *Pt 15, Ch 3, 6 Lubricating/hydraulic oil systems*.

8.8 Electrical systems

8.8.1 Electric motors are to meet the requirements of *Pt 16, Ch 2, 9 Rotating machines*. Motors exposed to weather are to have enclosures suitable for their location, *see also Pt 16, Ch 2, 1.11 Location and construction 1.11.1*.

8.8.2 Motor branch circuits are to be protected in accordance with the applicable Rules, and cable sizing is to be in accordance with the requirements of the *Pt 16, Ch 2, 11 Electric cables, optical fibre cables and busbar trunking systems (busways)*.

8.9 Control arrangements

8.9.1 All control devices are to be capable of being controlled from readily accessible positions and protected against unintentional operation.

8.9.2 The maximum travel of the levers is not to exceed 600 mm if movable in one direction only, or 300 mm to either side from a central position if movable in both directions.

8.9.3 Wherever practical, the lever is to move in the direction of the intended movement. If this cannot be achieved, then it is to move towards the right when hauling and towards the left when paying out.

8.9.4 For lever-operated brakes, the brake is to engage when the lever is pulled and disengage when the lever is pushed. The physical effort on the brake for the operator is not to exceed 160 N.

8.9.5 For pedal-operated brakes, the maximum travel is not to exceed 250 mm and the physical effort for the operator is not to exceed 320 N.

8.9.6 The handwheel or crankhandle is to actuate the brake when turned clockwise and release it when turned counterclockwise. The physical effort for the operator is not to exceed 250 N for speed regulation and 500 N at any moment.

8.9.7 When not provided with automatic sequential control, separate push-buttons are to be provided for each direction of operation.

8.9.8 The push-buttons are to actuate the machinery when depressed, and stop and effectively brake the machinery when released.

8.9.9 The above-mentioned individual push-buttons may be replaced by two ‘start’ and ‘stop’ push-buttons.

8.9.10 Control systems, whether electric, pneumatic or hydraulic, are to comply with the general requirements of *Pt 6, Ch 1, 2 General requirements*.

8.10 Protection arrangements

8.10.1 Where applicable, moving parts of windlass machinery are to be provided with suitable railings and/or guards to prevent injury to personnel.

8.10.2 Protection is to be provided for preventing persons from coming into contact with surfaces having temperatures over 50°C.

8.10.3 Steel surfaces not protected by lubricant are to be protected by a coating in accordance with the requirements of a relevant National or International Standard acceptable to LR.

8.10.4 For arrangements of power transmission systems and relief requirements, *see Pt 5, Ch 14, 9.1 General* of the Rules for Ships.

8.10.5 Electrical cables installed in exposed locations on open deck are to be provided with effective mechanical protection.

8.10.6 Means are to be provided to contain potential debris resulting from severe damage of the prime mover due to over-speed in the event of uncontrolled rendering of the cable, particularly when an axial piston type hydraulic motor forms the prime mover.

8.10.7 An arrangement to release the anchor and chain in the event of windlass power failure is to be provided. Windlasses are to be fitted with couplings which are capable of disengaging between the cable lifter and the drive shaft. Hydraulically or electrically operated couplings are to be capable of being disengaged manually.

8.10.8 The design of the windlass is to be such that the following requirements or equivalent arrangements will minimise the probability of the chain locker or forecastle being flooded in bad weather:

(a) a weathertight connection can be made between the windlass bedplate, or its equivalent, and the upper end of the chain pipe, by means of a cover or seal, and
(b) access to the chain pipe is adequate to permit the fitting of a cover or seal, of sufficient strength and proper design, over the chain pipe while the ship is at sea.

8.11 Shop inspection and testing

8.11.1 Windlasses are to be inspected during fabrication at the manufacturers' facilities by a Surveyor for conformance with the approved plans. Acceptance tests, as specified in the specified Standard (*see Pt 3, Ch 5, 8.1 General 8.1.2*), are to be witnessed by the Surveyor and include the following tests, as a minimum:

(a) No-load test. The windlass is to be run without load at nominal speed in each direction for a total of 30 minutes. If the windlass is provided with a gear change, an additional run in each direction for 5 minutes at each gear change is required.
(b) Load test. The windlass is to be tested to verify that the continuous duty pull, overload capacity and hoisting speed as specified in *Pt 3, Ch 5, 8.4 Windlass design 8.4.1* can be achieved.

    Where the manufacturer's works does not have adequate facilities, these tests, including the adjustment of the overload protection, can be carried out on board ship. In these cases, functional testing in the manufacturer's works is to be performed under no-load conditions.
(c) Brake capacity test. The holding power of the brake is to be verified through testing if not verified by calculation.

8.11.2 Windlass performance characteristics specified in *Pt 3, Ch 5, 8.11 Shop inspection and testing 8.11.1* are based on the following assumptions:

(a) one cable lifter only is connected to the drive shaft;
(b) continuous duty and short term pulls are measured at the cable lifter;
(c) hawse pipe efficiency assumed to be 70 per cent.

8.12 On-board testing

8.12.1 Each windlass is to be tested under working conditions after installation on board to demonstrate satisfactory operation. Each unit is to be independently tested for braking, clutch functioning, lowering and hoisting of the chain cable and anchor, proper riding of the chain over the cable lifter, proper transit of the chain through the hawse pipe and the chain pipe, and effecting proper stowage of the chain and the anchor. It is to be confirmed that anchors properly seat in the stored position and that chain stoppers function as designed if fitted. The braking capacity is to be tested by intermittently paying out and holding the chain cable by means of the application of the brake.

8.12.2 The mean hoisting speed, as specified in *Pt 3, Ch 5, 8.4 Windlass design 8.4.1.(e)* is to be measured and verified. For testing purposes, the speed is to be measured over two shots of chain cable and initially with at least three shots of chain (82,5 m or 45 fathoms in length) and the anchor submerged and hanging free. Following trials, the ship will be eligible to be assigned a descriptive note **specified design anchorage depth . . . metres**, which will be entered in column 6 of the *Register Book*.

8.12.3 Load testing is to be carried out if this was not previously completed as required by *Pt 3, Ch 5, 8.11 Shop inspection and testing 8.11.1.(b)*.

8.12.4 Where the depth of water in the trial area is inadequate, suitable equivalent simulating conditions will be considered as an alternative.

8.13 Marking and identification

8.13.1 The windlass is to be permanently marked with the following information:

(a) The size designation of the windlass (e.g. 100/3/45, where 100 is the nominal diameter of the chain cable in mm, 3 is the numeral in the chain cable steel grade U3, and 45 refers to the holding load expressed as a percentage of the chain cable breaking load).
(b) Maximum anchorage depth, in metres.

8.14 Seatings

8.14.1 The windlass is to be efficiently bedded and secured to the deck. The thickness of the deck in way of the windlass may need to be increased, and the supporting structure for the anchor windlass to be examined for the brake holding loads specified by *Pt 3, Ch 5, 8.4 Windlass design 8.4.1*. The allowable stresses specified in *Table 5.6.3 Allowable stresses in windlass and chain stopper supporting structure* are to be used to derive the net scantlings of the supporting structure. The capability of the supporting structure to withstand buckling is also to be assessed. Strength and buckling calculations are to be submitted for consideration. The structural design integrity of the bedplate is the responsibility of the Builder and windlass manufacturer.

■ *Section 9*
Structural details

9.1 Bulbous bow and wave piercing bow arrangements

9.1.1 The shell plating is to be increased in thickness at the fore end of the bulb and in other areas likely to be damaged by the anchors and chain cables. The increased plate thickness is to be the same as that required for plated stems by *Pt 6 Hull Construction in Steel*, *Pt 7 Hull Construction in Aluminium* and *Pt 8 Hull Construction in Composite* of the Rules for steel, aluminium alloy and composite materials respectively.

9.2 Hawse pipes and anchor recesses

9.2.1 Hawse pipes, bow rollers and other deck gear, of adequate size and construction, are to be provided for handling and securing the anchors and are to be efficiently attached to the structure and arranged to give an easy lead to the cable.

9.2.2 The hawse pipes are to be of sufficient size and thickness, and arranged to give an easy lead for the cable to the windlass.

9.2.3 Hawse pipes and anchor pockets are to be of ample thickness and of a suitable size and form to house the anchors efficiently, preventing, as much as practicable, slackening of the cable or movements of the anchor being caused by wave action. The shell plating and framing in way of the hawse pipes are to be reinforced as necessary, *see Pt 3, Ch 5, 9.4 Local reinforcement 9.4.1*. Substantial chafing lips are to be provided at shell and deck. These are to have sufficiently large, radiused faces to minimise the probability of cable links being subjected to high bending stresses. Alternatively, roller fairleads of suitable design may be fitted. Where unpocketed rollers are used, it is recommended that the roller diameter be not less than eleven times the chain diameter. Where hawse pipes are not fitted, alternative arrangements will be specially considered.

9.3 Spurling pipes

9.3.1 Satisfactory means are to be provided to prevent inadvertent flooding of chain lockers, *see Pt 3, Ch 5, 6.8 Cable locker*. Spurling pipes are to be provided with permanently attached closing appliances to minimise water ingress. Examples of acceptable arrangements are:

(a) steel plates with cutouts to accommodate chain links, or
(b) canvas hoods with a lashing arrangement that maintains the cover in the secured position.

9.4 Local reinforcement

9.4.1 The thickness of shell plating determined in accordance with the Rule requirements is to be increased locally by not less than 50 per cent in way of hawse pipes.

9.4.2 Supports under windlasses and winches are to be suitably reinforced.

■ *Section 1* General requirements

1.1 Scope

1.1.1 These Rules set down the criteria for the assessment of the noise and vibration on special service craft and are applied in addition to the other relevant requirements of these Rules.

1.1.2 For the purpose of these Rules, the term ‘ship’, unless otherwise stated, applies to Special Service Craft and Yachts.

1.1.3 The requirements of this Chapter may be applied where no other statutory requirements exist.

1.1.4 These Rules provide for two alternatives:

(a) **Class Notations** which indicate that the ship has been assessed and complies with noise and vibration criteria of these Rules and that a periodic survey regime has been established for the lifetime of the ship.
(b) **Certificate of Compliance** which provides evidence that the ship has been assessed and found to comply with the noise and vibration criteria of these Rules.

1.1.5 Spaces that comply with the noise level limits specified in *Table 6.2.5 Crew work areas - maximum noise levels in dB(A)* and under Acceptance Numeral 3 in *Table 6.2.2 Yachts - Maximum noise levels in dB(A)* and *Table 6.2.4 Crew accommodation - Maximum noise levels in dB(A)*, will meet the requirements of section 4 of IMO *Resolution MSC.337(91) – Adoption of the Code on Noise Levels on Board Ships – (Adopted on 30 November 2012)The Annex below is consolidated into Resolution MSC.337(91)*, when measured in accordance with the requirements of Section 4.

1.1.6 Spaces that comply with the noise level limits specified under Acceptance Numerals 1 and 2 in *Table 6.2.2 Yachts - Maximum noise levels in dB(A)* and *Table 6.2.4 Crew accommodation - Maximum noise levels in dB(A)*, will achieve enhanced levels of passenger and crew comfort as applicable, when measured in accordance with the requirements of Chapters 2 and 3 of IMO *Resolution MSC.337(91) – Adoption of the Code on Noise Levels on Board Ships – (Adopted on 30 November 2012)The Annex below is consolidated into Resolution MSC.337(91)*. All vessels can apply for Acceptance Numerals 1 and 2.

1.1.7 These Rules recognise existing National and International Standards and specify levels of noise and vibration currently achievable using good engineering practice. Compliance with these requirements will be assessed by review of procedures, inspection and measurement of the relevant parameters and pre-survey reviews. Inspections and measurements are to be conducted, witnessed or assessed by Lloyd's Register's Surveyors unless otherwise agreed by Lloyd's Register (hereinafter referred to as ‘LR’).

1.1.8 Accommodation comfort is a function of ship type and layout. These Rules address two types of ship:

(a) High-speed (e.g. surface effect ships, wave piercing catamarans, hydrofoils).
(b) Yacht (e.g. sailing yachts, motorised pleasure craft).

1.1.9 These Rules include levels of noise and vibration which should be verified by measurements following completion of the ship. It is recommended that the Builders undertake calculations of noise and vibration characteristics so that any potential problem areas can be identified and control measures implemented.

1.1.10 The sound pressure levels for audible alarms and public address systems fitted in accordance with other Sections of the Rules are to satisfy IMO Resolution A.830(19), Code on Alarms and Indicators.

1.2 Definitions

1.2.1 **Passenger spaces** are defined as all areas intended for passenger use, and include the following:

(a) Passenger cabins.
(b) Public spaces (e.g. restaurants, hospitals, lounges, reading and games rooms, gymnasiums, corridors and/or shops).
(c) Open deck recreation areas.

1.2.2 **Crew spaces** are defined as all areas intended for crew use only, and include the following:

(a) Accommodation spaces (e.g. cabins, offices, mess rooms, recreation rooms).
(b) Work spaces.
(c) Navigation spaces.

1.2.3 **Noise level** is defined as the A-weighted energy equivalent sound pressure level measured in accordance with ISO 2923.

1.2.4 **Vibration level** is defined by the application of ISO 20283-5. The vibration level is defined as the overall frequency weighted r.m.s. value of vibration during a period of steady-state operation over the frequency range 1 to 80 Hz.

1.3 Class notations

1.3.1 The class notations described in *Pt 3, Ch 6, 1.3 Class notations 1.3.2* provide standards for noise and vibration levels in different spaces at the time of delivery and during the ship's life if substantial changes to the machinery installation or interior arrangements are made.

1.3.2 The **PAC** (Passenger Accommodation Comfort), **CAC** (Crew Accommodation Comfort) and **PCAC** (Passenger and Crew Accommodation Comfort) notations are optional and are primarily intended to apply to passenger ships. If requested, however, any ship can be assessed for compliance, using these requirements as the basis for the assessment and a LR Certificate of Compliance issued (*see Pt 3, Ch 6, 1.1 Scope 1.1.4.(b)* and *Pt 3, Ch 6, 1.4 Certificate of Compliance*).

1.3.3 The **PAC** notation indicates that the passenger accommodation meets the acceptance criteria whilst the CAC notation indicates that the crew accommodation and work areas meet the acceptance criteria. The **PCAC** notation indicates that the passenger and crew spaces both meet the acceptance criteria.

1.3.4 For ships which achieve the noise and vibration comfort standards specified in these Rules, the notation **PAC**, **CAC** or **PCAC** will be assigned.

1.3.5 Following the **PAC** or **CAC** notation, numerals **1**, **2** or **3** will indicate the acceptance criteria to which the noise and vibration levels have been assessed. In the case of the PCAC notation, two numerals will be assigned. The first will indicate the acceptance criteria for passenger accommodation, whilst the second will indicate the crew comfort criteria.

1.3.6 For particular vessels, impact insulation and transient noise in accordance with *Pt 3, Ch 6, 2.5 Impact insulation* and *Pt 3, Ch 6, 2.6 Transient noise* together with any additional or more stringent noise and vibration criteria may be assessed within the scope of the notations where agreed between the Owner, Builder and LR.

1.4 Certificate of Compliance

1.4.1 A Certificate of Compliance records that a ship has been designed and constructed to satisfy the noise and vibration criteria contained in these Rules. This is to be confirmed by measurements and reporting in accordance with Sections *Pt 3, Ch 6, 4 Testing* and *Pt 3, Ch 6, 5 Noise and vibration survey reporting*.

1.4.2 A Certificate of Compliance is optional and if requested, any ship can be assessed for compliance using the Rule requirements.

1.4.3 Where noise and vibration levels are at variance with those prescribed by these Rules, they will be added to the certificate for information purposes.

1.4.4 A Certificate of Compliance will be issued after the initial survey required by Section *Pt 3, Ch 6, 6 Non periodical survey requirements*.

Section 2
Noise

2.1 Assessment criteria

2.1.1 Where a space is occupied by both passengers and crew, the more stringent of the relevant requirements apply unless agreed between the Builder and Owner and advised to LR.

2.2 Passenger accommodation and public spaces

2.2.1 Under test conditions specified in *Pt 3, Ch 6, 4.2 Test conditions*, the applicable noise levels specified in *Table 6.2.1 High speed craft - Maximum noise levels in dB(A)* and *Table 6.2.2 Yachts - Maximum noise levels in dB(A)* should not generally be exceeded. *See Pt 3, Ch 6, 2.2 Passenger accommodation and public spaces 2.2.3*.

Table 6.2.1 High speed craft - Maximum noise levels in dB(A)

Location		Acceptance Numeral		
		1	2	3
Public spaces:	Excluding shops	60	65	70
	Shops	65	68	72

Table 6.2.2 Yachts - Maximum noise levels in dB(A)

Location		Acceptance Numeral		
		1	2	3
Passenger cabins:	Standard	53	55	58
	Superior	50	53	55
Lounges		55	58	60
Open deck recreation areas:	2nd deck from WL	72	75	79
	3rd deck from WL	63	66	70
Wheelhouse		60	62	75

Note 1. The levels may be exceeded by 3dB(A) in accommodation above the propellers for three decks above the mooring deck.

Note 2. The levels for open deck recreation areas refer to ship generated noise only. On open deck spaces the noise generated from the effects of wind and waves can be considered separately to limits agreed between the Builder and Owner and advised to LR for the trial conditions.

2.2.2 For cabins bordering discotheques and similar entertainment spaces, the deck and bulkhead sound insulation is to be sufficient to ensure that the maximum cabin noise levels are not exceeded even when high external noise levels prevail. Noise from entertainment spaces shall be considered as transient noise and should meet the requirements stated in *Pt 3, Ch 6, 2.6 Transient noise*.

2.2.3 Acceptance of noise levels greater than those specified in *Table 6.2.1 High speed craft - Maximum noise levels in dB(A)* and *Table 6.2.2 Yachts - Maximum noise levels in dB(A)* may be considered where agreed between the Owner and Builder at specification/contract stage. Not more than 20 per cent of the passenger cabins, 30 per cent of the public spaces and 20 per cent of the crew cabins should exceed the relevant noise criteria by more than 3 dB(A).

2.2.4 Acoustic insulation of bulkheads and decks between passenger spaces is to be generally in accordance with the values of the weighted apparent sound reduction index, R'_w, as given in *Table 6.2.3 Minimum apparent airborne sound insulation indices, R'_w*, calculated using ISO 717/1. *See also Pt 3, Ch 6, 2.2 Passenger accommodation and public spaces 2.2.6*.

Table 6.2.3 Minimum apparent airborne sound insulation indices, R'_w

Location		Acceptance Numeral		
		1	2	3
Passenger cabins:	Standard	41	39	38
	Superior	45	42	40
Cabin to corridor:	Standard	38	36	35
	Superior	42	40	37
Cabin to stairway:	Standard	47	45	43
	Superior	50	47	45
Cabin to public space (excluding corridoors/stairwells and discotheques):	Standard	52	48	48
	Superior	55	50	50
Discotheques to cabins		60	60	60
Discotheques to stairwells and public spaces		52	52	52
Cabin to machinery rooms and engine casing		55	53	50

2.2.5 For the purpose of selecting acoustic sound insulation, the following sound noise levels may be used The frequency spectrum used should be as defined in ISO 717-1: spectrum No. 2 for discotheques and spectrum No. 1 for others. Evaluation should include the frequency range down to 50 Hz 1/3-octave band:

(a) Cabins – 80 dB(A).
(b) Dining Rooms – 85 dB(A).
(c) Corridors – 90 dB(A).
(d) Discotheques, Theatres, Entertainment Areas – 105 dB(A).

2.2.6 Acceptance of bulkhead and deck acoustic insulation values less than those specified in *Table 6.2.3 Minimum apparent airborne sound insulation indices, R'_w* may be considered where agreed between the Owner and Builder. Not more than 20 per cent of the interfaces tested should have airborne sound insulation indices, R'_w, more than 3 dB(A) lower than the minimum specified values.

2.3 Crew accommodation and work areas

2.3.1 Under the applicable test conditions specified in *Pt 3, Ch 6, 4.2 Test conditions*, the noise levels specified in *Table 6.2.4 Crew accommodation - Maximum noise levels in dB(A)* and *Table 6.2.5 Crew work areas - maximum noise levels in dB(A)* are not to be exceeded.

2.3.2 Crew space insulation is to comply with the requirements of IMO *Resolution MSC.337(91) – Adoption of the Code on Noise Levels on Board Ships – (Adopted on 30 November 2012)The Annex below is consolidated into Resolution MSC.337(91)*.

Table 6.2.4 Crew accommodation - Maximum noise levels in dB(A)

Location	Acceptance Numeral			
	1	2	3	
			Ships <10,000 grt	Ships ≥ 10,000 grt
Sleeping cabins, hospitals	50	53	60	55
Offices, conference rooms and day cabins	55	58	65	60
Mess rooms, lounges, reception areas and recreation rooms within accommodation	55	58	65	60

Recreational areas on open deck	67	72	75	75
Alleyways, changing rooms, bathrooms, lockers	70	75	75	75

Table 6.2.5 Crew work areas - maximum noise levels in dB(A)

Location	dB(A) level
Machinery space(not continuously manned) e.g. pump, refrigeration, thrusters or fan rooms	110
Wheelhouse, chartrooms, radar rooms	85
Machinery control rooms	75
Wheelhouse, chartrooms, radar rooms	65
Look-out posts e.g. at bridge wing or window Additional limits: • 250 Hz band • 500 Hz band (measured according to IMO A.343(IX))	70 68 63
Radio room	60
Galleys and pantries: • Equipment not working • Individual items at 1 metre	 75 80
Normally unoccupied spaces (e.g. holds, decks)	90
Ship's whistle, on bridge or forecastle	110

2.4 Maximum noise levels

2.4.1 Where the measured noise level exceeds the specified criterion by 3 dB(A), or contains subjectively annoying low frequency or tonal components, the noise rating (NR) number is to be established in accordance with the graph shown in *Figure 6.2.1 Noise rating curves*. This is achieved by plotting the linear octave band levels on the graph; the NR number is that NR curve to which the highest plotted octave band level is anywhere tangent. The specified criterion may be considered satisfied if the NR number does not exceed the specified A-weighted value minus 5 dB(A).

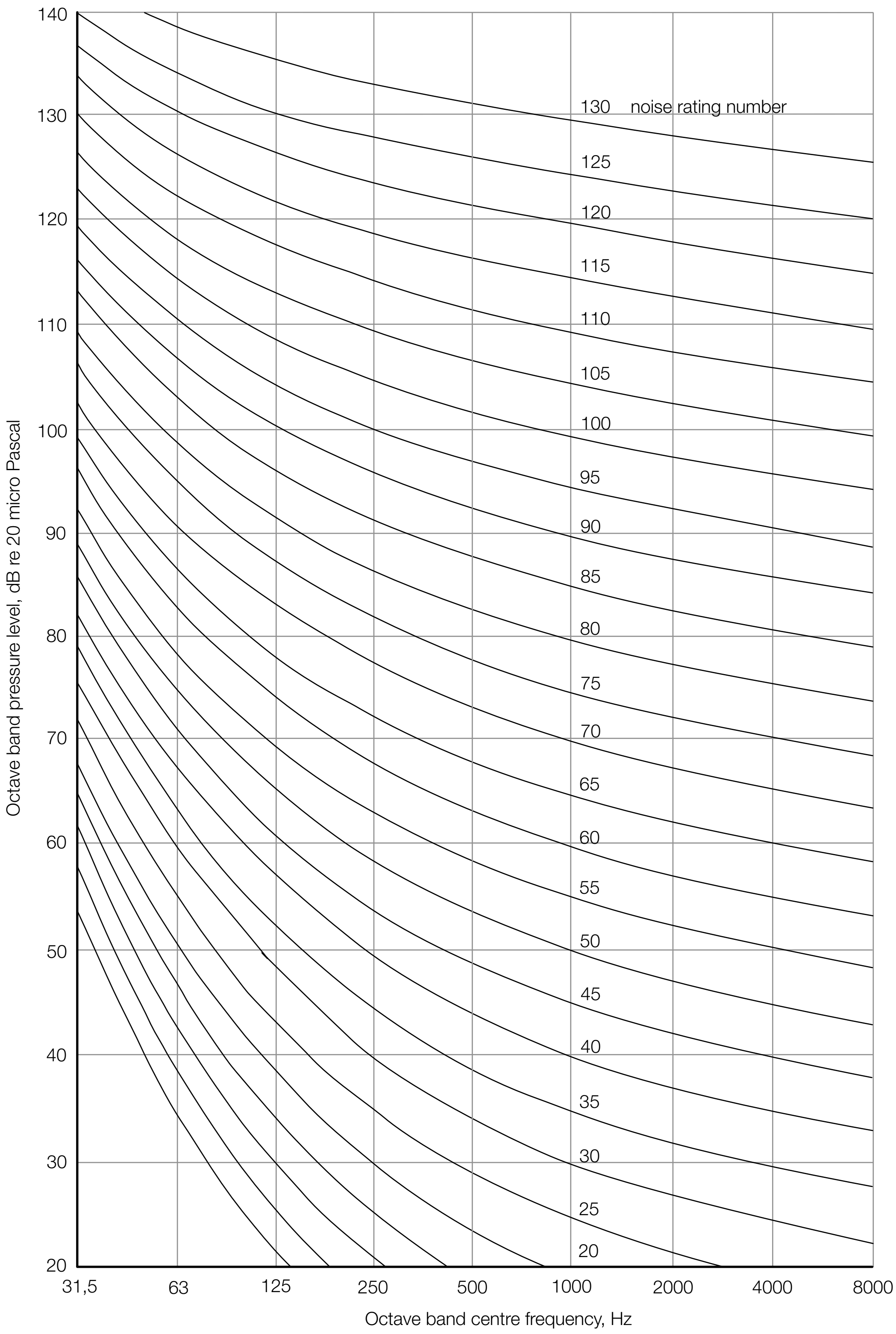


Figure 6.2.1 Noise rating curves

2.4.2 Guidance on maximum acceptable sound pressure levels and noise exposure limits for crew spaces is given in IMO *Resolution MSC.337(91) – Adoption of the Code on Noise Levels on Board Ships – (Adopted on 30 November 2012)The Annex below is consolidated into Resolution MSC.337(91)*.

2.5 Impact insulation

2.5.1 Where agreed between the Owner, Builder and LR, enhanced criteria for noise levels recognising the effects of impact sound pressures may be applied in accordance with *Pt 3, Ch 6, 2.5 Impact insulation 2.5.2*.

2.5.2 For passenger and crew cabins located below or adjacent to dance floors, stages, aerobics and gymnasium areas, jogging tracks or other areas where impact noise is generated, the normalised field measured impact sound pressure level within the cabins is not to exceed 45 dB.

2.5.3 For public rooms under dance floors, stages, aerobics and gymnasium areas, jogging tracks or other areas where impact noise is generated, the normalised field measured impact sound pressure level within the space is not to exceed 55 dB.

2.5.4 For passenger cabins, normalised field measured impact sound pressure level, $L'_{n,w}$, calculated using ISO 717/2, is to be generally in accordance with the values stated in *Table 6.2.6 Passenger cabins normalised field measured impact sound pressure level* $L'_{n,w}$. *See also Pt 3, Ch 6, 2.5 Impact insulation 2.5.5*.

Table 6.2.6 Passenger cabins normalised field measured impact sound pressure level $L'_{n,w}$

Location	dB
Below decks covered with carpet and soft materials	50
Below decks covered with hard materials (such as wood, marble or similar	60
Below dance floors, theatre or sports rooms	45

2.5.5 Acceptance of normalised impact sound pressure levels greater than those specified in *Table 6.2.6 Passenger cabins normalised field measured impact sound pressure level* $L'_{n,w}$ may be considered for assignment of the applicable class notation where agreed between the Owner, Builder and LR. No more than 20 per cent of the passenger cabins tested should exceed the levels specified by more than 3 dB.

2.6 Transient noise

2.6.1 Where agreed between the Owner, Builder and LR, enhanced criteria for transient noise levels may be applied in accordance with *Pt 3, Ch 6, 2.6 Transient noise 2.6.2*.

2.6.2 The maximum sound pressure level ($L_{pAS,max}$) emanating from any machinery or system caused by a single event that produces a noise ‘spike’ compared to the reference condition sound level (such as vacuum systems or valve operations) is not to cause an increase in noise in comparison with the reference condition (background noise) as below:

(a) Passenger cabins and public areas: +2 dB(A)

(b) Officer cabins: +2 dB(A)

(c) Crew cabins and public areas: +3 dB(A)

A tolerance of +3 dB(A) may be applied to 5 per cent of cabins and public areas in each fire zone on each deck. This criterion is generally applicable to the specified maximum noise levels for the space concerned.

Section 3
Vibration

3.1 Assessment criteria

3.1.1 Where a space is occupied by both passengers and crew, the more stringent of the relevant requirements apply unless agreed between the Builder and Owner and this agreement advised to LR.

3.1.2 The limits apply to vertical, longitudinal and transverse vibrations which are to be assessed separately.

3.1.3 Under test conditions specified in *Pt 3, Ch 6, 4.2 Test conditions*, the applicable vibration levels specified in *Table 6.3.1 High speed craft - Maximum vibration levels*, *Table 6.3.2 Yacht - Maximum vibration levels* and *Table 6.3.3 Crew spaces - Maximum vibration levels* should not be exceeded.

Table 6.3.1 High speed craft - Maximum vibration levels

Standard:	ISO 20283-5		
Units:	Frequency weighted velocity level (1–80 Hz), mm/s r.m.s.		
	Acceptance Numeral		
Location	1	2	3
Public spaces	2,5	3,2	3,6

Table 6.3.2 Yacht - Maximum vibration levels

Standard:	ISO 20283-5		
Units:	Frequency weighted velocity level (1–80 Hz), mm/s r.m.sua		
	Acceptance Numeral		
Location	1	2	3
Cabins and lounges	1,8	2,0	2,5
Public spaces	2,5	2,9	3,3
Open recreation decks	2,5	3,2	3,8
Note The vibration level may be exceeded by 0,3 mm/s in the yacht's aft body directly above the propellers.			

Table 6.3.3 Crew spaces - Maximum vibration levels

Standard:	ISO 20283-5
Units:	Frequency weighted velocity level (1–80 Hz), mm/s
Location	
Accommodation and navigation spaces	3,5
Work spaces	5,0

3.1.4 Acceptance of vibration levels greater than those specified in *Table 6.3.1 High speed craft - Maximum vibration levels*, *Table 6.3.2 Yacht - Maximum vibration levels* and *Table 6.3.3 Crew spaces - Maximum vibration levels* may be considered for assignment of the applicable class notation where agreed between the Owner, Builder and LR.

3.2 Passenger accommodation and public spaces

3.2.1 Passenger spaces are to comply with the overall vibration levels specified in *Table 6.3.1 High speed craft - Maximum vibration levels* and *Table 6.3.2 Yacht - Maximum vibration levels*.

3.2.2 No more than 20 per cent of all passenger spaces/areas and public spaces should exceed the relevant vibration criteria specified in *Table 6.3.1 High speed craft - Maximum vibration levels* and *Table 6.3.2 Yacht - Maximum vibration levels* by more than 0,3 mm/s.

3.3 Crew accommodation and work spaces

3.3.1 Crew spaces are to comply with the overall vibration levels specified in *Table 6.3.3 Crew spaces - Maximum vibration levels*.

■ *Section 4* Testing

4.1 Measurement procedures

4.1.1 These requirements take precedence where quoted standards may differ.

4.1.2 The trial measurements may be undertaken by an approved technical organisation as defined in *Pt 3, Ch 6, 4.7 Approved technical organisation* or by LR. In the former case, the measurements are to be witnessed by an LR Surveyor.

4.1.3 Subject to agreement by LR and the Owner/ Operator, the measurements may be undertaken by the Builder. In this case, the measurements are to be witnessed by an LR Surveyor.

4.2 Test conditions

4.2.1 Test conditions for the surveys are to be in accordance with those detailed in ISO 2923 and ISO 20283-5, as applicable.

4.2.2 The intended operating and loading conditions of the ship during assessment surveys are to be submitted to LR for agreement, prior to commencement of surveys.

4.2.3 Surveys are to be conducted when the ship is fully outfitted and all systems contributing to noise and vibration levels are operational.

4.2.4 The test conditions required for the vibration and noise measurements are to be in accordance with the following conditions:

(a) For high speed craft and yachts, prior to measurement surveys being carried out, the ship operating condition where the worst conditions are experienced between 0 and 85 per cent maximum continuous rating of the propulsion machinery is to be determined. To establish this condition, four measurement positions are to be defined with the agreement of LR and measurements taken of the parameters of interest at ship speeds corresponding to percentages of the maximum continuous rating of the propulsion machinery increasing up to 40 per cent MCR in 10 per cent intervals and from 40 per cent in 5 per cent intervals up to the 85 per cent maximum continuous rating of the propulsion machinery. If the 85 per cent maximum continuous rating condition is found to be the worst condition, then this will form the trial operating conditions. However, if a lower speed condition is found to be worse than the 85 per cent maximum continuous rating condition then both that condition and the 85 per cent maximum continuous rating condition will form the trial operating conditions. Where unavoidable, any barred range within the values required for the trial operating condition may be excluded on agreement between Owner and Builder subject to approval by LR.

(b) The power absorbed by the propeller(s) is to be that defined in *Pt 3, Ch 6, 4.2 Test conditions 4.2.4*. Alternatively, by special agreement, some lesser power could be accepted if it can be demonstrated by the Owner that this would correspond to a more representative normal service condition.

(c) Auxiliary machinery essential for the ship's operating conditions together with HVAC systems are to be running at their normal rated capacity during the noise and vibration trials. Combinations of auxiliary machinery operation may be necessary. In addition, the following equipment is to be running if appropriate: stabilisers, waste treatment equipment, swimming pool and jacuzzi equipment.

(d) For sea-going ships, measurements are to be taken with the ship proceeding ahead, at a constant speed and course, in a depth of water not less than five times the draught of the ship. For other ships, an appropriate water depth is to be agreed with LR prior to the trials.
(e) Trials are to be conducted in sea conditions not greater than sea state 3 on the WMO sea state code. In addition, noise measurements should not be taken when the wind force exceeds 4 on the Beaufort scale.
(f) The ship is to be at a displacement and trim representative of an operating condition.
(g) Rudder angle variations are to be limited to ±2° of the midship position and rudder movements are to be kept to a minimum throughout the measurement periods.
(h) In addition, for ships which are designed to spend a considerable period of time in harbour, the noise and vibration, are to be measured for this condition, with the auxiliary machinery and HVAC systems running at their normal rated capacity.
(i) For all ships, intermittently run equipment such as transverse propulsion units are to be operated at 40 per cent of their rated power for additional measurements in surrounding ship areas.

4.2.5 Prior to survey, a test programme is to be submitted for approval by LR. This programme is to contain details of the following:

(a) Measurement locations indicated on a general arrangement of the ship.
(b) The ship's loading condition during survey.
(c) The machinery operating condition, including HVAC system, during survey.
(d) Noise and vibration measuring equipment.

4.3 Noise measurements

4.3.1 Noise measurements are to be conducted in accordance with ISO 2923 and IMO *Resolution MSC.337(91) – Adoption of the Code on Noise Levels on Board Ships – (Adopted on 30 November 2012)The Annex below is consolidated into Resolution MSC.337(91)*. Measurements of noise levels are to be carried out using precision grade sound level meters conforming to IEC 60651, Type 1 or 2. Subject to demonstration, equivalent Standards are acceptable.

4.3.2 Where the measured noise level exceeds the relevant criterion by 3 dB(A), or contains subjectively annoying low frequency noise or obvious tonal components, octave band readings are to be taken, with centre frequencies from 31,5 Hz to 8 kHz.

4.3.3 When outfitting is complete, and all soft furnishings are in place, sound insulation indices for passenger spaces are to be determined in accordance with ISO 16283-1. Cabin to cabin indices are to be determined from a minimum of three locations for each cabin type within the passenger accommodation, the number of test locations being agreed with LR. If the partition surface area is less than 10 m^2, an area of 10 m^2 shall be used for the calculation of the R'_w index, unless otherwise agreed.

4.3.4 If required, impact sound measurements are to be carried out in accordance with ISO 16283-2 and presented in accordance with ISO 717/2. *See Pt 3, Ch 6, 4.4 Noise measurement locations 4.4.4*.

4.4 Noise measurement locations

4.4.1 Measurement locations are to be chosen so that the assessment represents the overall noise environment on board the ship. In addition to the requirements of IMO *Resolution MSC.337(91) – Adoption of the Code on Noise Levels on Board Ships – (Adopted on 30 November 2012)The Annex below is consolidated into Resolution MSC.337(91)* for crew spaces, all public spaces and all passenger spaces are to be measured.

4.4.2 During measurement trials, recognized noise sources are to be operated at their normal level of noise output (e.g. machinery at design rating).

4.4.3 In larger sized spaces, where noise levels may vary considerably, such as restaurants, lounges, atria and open deck recreation areas, measurements are to be taken at locations not greater than 7 m apart.

4.4.4 For high speed craft having large passenger saloons, measurements are to be taken along the centreline and along both sides of the saloons at locations not greater than 7 m apart.

4.4.5 The number of and locations for impact noise measurements are to be agreed between the Builder, Owner and LR. The measurements are to be carried out when the ship is in a condition with steady and low background noise. The number and location of measurements are to take account of all different combinations of construction, areas of application, types of cabin and spaces below.

4.5 Vibration measurements

4.5.1 Vibration measurements are to be conducted in accordance with ISO 20283-5.

4.5.2 Measurements are to be made with instrumentation meeting the requirements of ISO 8041.

4.5.3 Vibration levels are to be given in terms of the velocity measurement appropriate to the version of the standard being used and should be measured over a period of not less than one minute.

4.6 Vibration measurement locations

4.6.1 Measurement locations are to be chosen so that the assessment represents the overall vibration environment onboard the ship. To minimise survey times, readings may be taken at the locations previously defined for the noise assessment part of the survey.

4.6.2 In cabins, vibration readings are to be taken in the centre of the floor area. The measurements are to indicate the vibration of the deck structure. In large spaces, such as restaurants, sufficient measurements are required to define the vibration profile.

4.6.3 Where deck coverings make transducer attachment impracticable, use of a small steel plate having a mass of at least 1 kg, with spikes as appropriate, is permissible.

4.6.4 At all locations, vibrations in the vertical direction are to be assessed. Sufficient measurements in the longitudinal and transverse directions are to be taken to define global deck vibrations in at least two locations on each deck.

4.7 Approved technical organisation

4.7.1 An approved technical organisation for the purposes of these Rules is one that is acceptable to the Owner and LR with proven capability in noise and vibration measurement and satisfies all the criteria set out below:

(a) Have instrumentation whose calibration, both before and after the measurements, can be traced back to National Standards and, hence, back to International Standards.
(b) Have analysis procedures capable of data reduction to the requirements and standards set out in these Rules.
(c) Be able to provide a written report in English with contents as defined by *Pt 3, Ch 6, 5 Noise and vibration survey reporting*.

■ *Section 5*
Noise and vibration survey reporting

5.1 General

5.1.1 Prior to survey, a noise and vibration measurement plan is to be agreed by the Owner, Builder and LR.

5.1.2 The survey report is to comprise the data and analysis for both noise and vibration and is to be submitted to LR for consideration.

5.1.3 The survey report is to be prepared by the organisation undertaking the trial measurements, which may be an approved technical organisation or LR.

5.1.4 The survey report is to be submitted to LR for evaluation and confirmation that the results are in accordance with the noise and vibration levels specified in these Rules and/or agreed between the Owner and Builder. The assignment of a Class Notation or the issue of a Statement of Compliance will be subject to confirmation by an LR specialist with a competency level of 2 or higher within Passenger and Crew Accommodation comfort (PCAC) (ADV198).

5.2 Noise

5.2.1 The reporting of results is to comply with ISO 2923 and IMO *Resolution MSC.337(91) – Adoption of the Code on Noise Levels on Board Ships – (Adopted on 30 November 2012)The Annex below is consolidated into Resolution MSC.337(91)*, and is to include:

(a) Measurement locations indicated on a general arrangement plan including, where possible, the measured dB(A) level.

(b) Tabulated dB(A) noise levels, together with octave band analysis for positions where the level exceeds the specified criterion by 3 dB(A), or where subjectively annoying low frequency or tonal components were present. The Noise Rating number is also to be given where octave band analyses have been conducted.

(c) Ship and machinery details.

(d) Trial details:

- Loading condition.
- Machinery operating condition.
- Speed.
- Average water depth under keel.
- Weather conditions.
- Sea state.
- Draught.

(e) Details of measuring and analysis equipment (e.g. manufacturer, type and serial numbers), including frequency analysis parameters (e.g. resolution, averaging time, window function).

(f) Copies of the relevant instrument calibration certificates, together with the results of field calibration checks.

5.3 Vibration

5.3.1 The report is to contain the following information:

(a) Measurement positions indicated on a general arrangement plan.

(b) Where ISO 20283-5 is used, the frequency-weighted overall r.m.s. vibration levels tabulated for all measurement locations calculated using the weighting functions and methodology stated in the standard.

(c) Where ISO 6954:1984 is used, the maximum peak vibration levels and their corresponding frequencies taken from the frequency spectra, tabulated for all measurement locations.

(d) Ship and machinery details.

(e) Trial details:

- Loading condition.
- Machinery operating condition.
- Speed.
- Average water depth under keel.
- Weather conditions.
- Sea state.
- Draught.

(f) Frequency analysis parameters (e.g. resolution, averaging time and window function), if the analysis is done in the frequency domain.

(g) Copies of the relevant instrument calibration certificates, together with the results of field calibration checks.

■ *Section 6*
Non periodical survey requirements

6.1 Class notation assignment

6.1.1 Where the assignment of a Class Notation or a Statement of Compliance is requested, an Initial Survey is to comprise sea trial or initial in-service testing, reporting and assessment against the criteria set out in these Rules.

6.1.2 The sea trial or initial in-service testing requirements are set out in *Pt 3, Ch 6, 4 Testing*, and are to be reported in accordance with *Pt 3, Ch 6, 5 Noise and vibration survey reporting* and evaluated against the requirements of Sections *Pt 3, Ch 6, 2 Noise* and *Pt 3, Ch 6, 3 Vibration*.

6.2 Maintenance of class notation through-life and following modifications

6.2.1 Where an Owner has requested assignment of a Class Notation, arrangements are to be agreed between LR and the Owner to record observations/ complaints of excessive noise and vibration that have been such as to disturb the comfort of passengers and crew. The records of the observations are to be made available to the attending LR Surveyor at each Annual Survey.

6.2.2 Where the observations indicate that the noise and/or vibration levels may exceed the criteria relating to the Class Notation requirements and those measured at the Initial Survey, a measurement programme is to be agreed between the Owner and LR and measurements taken in accordance with these Rules.

6.2.3 A Renewal Survey may be required following modifications, alterations or repairs including replacement of major machinery items. It is the responsibility of the Owner to advise LR of such modifications.

■ *Section 7* Referenced standards

7.1 Noise

7.1.1 The following National and International Standards for noise are referred to in these Rules:

- ISO 2923:1996/Cor 1:1997, *Acoustics – Measurement of noise on board vessels*.
- ISO 717-1:2013, *Acoustics – Rating of sound insulation in buildings and of building elements; Part 1: Airborne sound insulation*.
- ISO 717-2:2013, *Acoustics – Rating of sound insulation in buildings and of building elements: Part 2: Impact sound insulation*.
- IMO *Resolution MSC.337(91) – Adoption of the Code on Noise Levels on Board Ships – (Adopted on 30 November 2012)The Annex below is consolidated into Resolution MSC.337(91)*.
- IEC 61672, *Sound level meters* (all parts), or earlier versions..
- ISO 16283-1:2014/Amd 1:2017, *Acoustics – Field measurement of sound insulation in buildings and of building elements – Part 1: Airborne sound insulation*.
- ISO 16283-2:2018, *Acoustics – Field measurement of sound insulation in buildings and of building elements – Part 2: Impact sound insulation*.

7.2 Vibration

7.2.1 The following National and International Standards for vibration are referred to in these Rules:

- ISO 20283-5:2016, *Mechanical vibration — Measurement of vibration on ships — Part 5: Guidelines for measurement, evaluation and reporting of vibration with regard to habitability on passenger and merchant ships.*
- ISO 8041-1:2017, *Human response to vibration – Measuring instrumentation – Part 1: General purpose vibration meters* (or earlier versions).

■ *Section 1* General

1.1 Applicability

1.1.1 This Chapter applies to craft that are fitted with a rig used for propulsion by wind force.

1.1.2 This Chapter applies to the rig insofar as this structure is used for propulsion purposes. The actual propulsion force may be generated by sails that are hoisted on the mast (e.g. fore-and-aft rig), rotation of the mast structure itself (e.g. Flettner rotors), or other means that capture wind force and transfer it to the hull (e.g. DynaRig).

1.1.3 Other elements of wind propulsion systems such as sails and running rigging are excluded from this Chapter.

1.1.4 Rigs, from an arrangement point of view, that do not fit into the assessment structure as laid out in this Chapter, will be considered on an equivalence basis.

1.1.5 Attention is drawn to the requirements of the Flag Administration regarding the application of certain materials, systems, criteria or practices.

1.2 Definitions

1.2.1 'The rig' in this Chapter is defined as all the structure and equipment essential for the safe operation of a wind propulsion system.

1.3 Class notations

1.3.1 **RIGGING**. The **RIGGING** notation will be assigned where a new craft is fitted with a rig used for propulsion by wind force which is in accordance with the Rules.

1.3.2 **RIGGING***. Upon request, the **RIGGING*** notation will be assigned where an existing craft is fitted with a rig used for propulsion by wind force where:

- the rig design complies with requirements of this Chapter;
- maintenance records starting at the time of first stepping are available and assessed;
- service history is available and assessed; and
- a rig behaviour trial is carried out. *See Pt 3, Ch 7, 6 Rig behaviour trial*.

1.4 Submissions requirements

1.4.1 In addition to submissions required by *Pt 3, Ch 1, 5 Information required*, plans and information are to be submitted as required in *Table 7.1.1 Plans and particulars to be submitted* as applicable.

Table 7.1.1 Plans and particulars to be submitted

Document	For information, *see* Note	For appraisal, *see* Note
Technical Construction File (TCF) *see Pt 3, Ch 7, 1.5 The Technical Construction File*, additionally including:		X
Transport and handling procedures		
Dock tune procedure		
Maintenance manual		
Material certification		
General wind propulsion layout plan	X	
Deck hardware plan	X	
Deck fittings for cleats, sheet winches, sheet tracks, travellers, etc. and through-deck fittings	X	
Mast, spreader and spar sections		X
Limit load and working load on mast foundation	X	
Mast loadings	X	
Bowsprit arrangement with all its stays and loadings	X	
Rig loadings	X	
Mast step	X	
Mast bearing integration and its foundation in the case of AeroRig/ DynaRig		X
Chainplates, furlers, forestay and backstay attachments	X	
Ballast keel securing arrangements including information of the mass of the keel and ballast and its centre of gravity, including keel trunk	X	
Dagger board arrangement	X	
Rudder skeg construction and support details	X	
Note X indicates reason for submission.		

1.5 The Technical Construction File

1.5.1 A Technical Construction File (TCF) is to be maintained during the design, construction, stepping and commissioning phases.

1.5.2 The TCF will be the basis for appraisal.

The TCF will include a:

- Global design description which is to include a sail plan(s) with standing and running rigging shown. The sails that are carried on board and that can be used in the sailing conditions are to be described.
- Methodology description which gives the methods used for calculations and predictions, and explains the computational approach applied to the rig scantling design.
- Load case definition. A list of load cases for which the rig is designed. As a minimum, the applied load cases will be limit cases. The load case definition is to include:
  - operation at sea;
  - manufacture (if considered applicable);

    - transport;
    - stepping;
    - maintenance (if considered applicable); and
    - survival.
- Structural design definition, which is a collection of documents and plans showing dimensions, materials, and cross-sections of all elements making up the structural integrity of the rig. Limit loads are to be defined for each of the elements. *See also Pt 3, Ch 7, 2.3 Stress factors (SF)*.
- Design evaluation report, which is to show that, in any of the design load cases, the loads on elements do not exceed permissible values. Rig foundation loads (e.g. mast step, chain plates, winch foundations and strong points) are part of the hull appraisal but may be taken into consideration in the design evaluation report.
- Materials certification report, which includes a declaration from the manufacturer that all construction materials are compliant with the structural design definition and will be examined using spot checks.
- Rig stepping report, which is to include the transport and stepping procedure as provided by the manufacturer and is to be to the satisfaction of the attending Surveyor.
- Rig behaviour report, which is to include a minimum of three sailing conditions which are included in the rig operation manual. It is a factual statement of observations made during trials with particular focus on agreement between predicted condition and actual performance. The report and observations are to be to the satisfaction of the attending Surveyor.
- Rig maintenance manual which is, as a minimum, to include maintenance instructions from the manufacturers of parts affecting safety and durability, clearly scheduled maintenance tasks that can be recorded in the ship's logbook and descriptions of the procedures for inspection. Attention is drawn to the *Code of safe working practices for merchant seafarers (COSWP)*.

■ *Section 2* Rig calculation requirements

2.1 Modelling of the rig elements

2.1.1 Appropriate rig materials are selected by the designer. Modelling and assessment are done using techniques corresponding to the material of rig element.

2.1.2 Composite material is non-isotropic. Mid-plane methods may be used for global evaluation of in-plane stress in cases with balanced fibre layup. Any load transfer through the thickness of the material is to be considered to be carried by the matrix material only. The difference between the strength of the matrix material and the strength of the fibres is to be taken into account.

2.1.3 Metallic materials are isotropic but analysis is to be done using thin walled sections where appropriate and geometric accurate volume models where possible.

2.1.4 The analysis shall account for the load factors with respect to potential failures through global buckling, shear stiffness of spar tubes, thin-wall buckling, and other stability evaluations used in the design process.

2.1.5 Results are to be represented in a phenomenological material failure index such as the Tsai-Wu failure criterion. Individual component failure index values for compressive, tensile and shear strength are not considered suitable for evaluation.

2.2 Load cases

2.2.1 Sailing condition load cases are to be applied to the rig. Reference is made to LR's *Guidance Notes for the Certification of Masts, Spars and Standing Rigging, January 2017* for a minimal set of requirements when determining these loads.

2.2.2 All load cases are to be identified with a load case number.

2.2.3 Load cases that cover operation at sea are to include sails set, limiting wind and sea conditions with corresponding angle of heel and wind direction. A reefed storm condition may need to be considered depending on the operational profile of the craft.

2.2.4 Load cases in the manufacture, transport, installation and stepping/unstepping are to include but may not be limited to:

(a) Lifting operations:

- With the correct number of lifting slings for each operation.

- With a lifting acceleration of 0,5g.

(b) Laying down:

- With the correct number of support points for each operation.

Load case assumptions are to be checked against handling procedures.

2.2.5 Loads in the survival condition are to be based on:

(a) Motions estimated from model tests or computation. In the absence thereof, accelerations and amplitudes given in *Table 7.2.1 Motions* may be applied.

(b) Wind speed of 63 m/s is to be assumed.

Table 7.2.1 Motions

Motion	Maximum single amplitude	Period in seconds
Roll	$\Phi = \sin^{-1}\theta$ degrees but need not exceed 30° and is not to be taken less than 22°.	$T_r = \frac{0,7B}{\sqrt{GM}}$
Pitch	$\Psi = 12e^{-0,0033L_{pp}}$ degrees but need not exceed 8°.	$T_p = 0,5\sqrt{L_{pp}}$
Heave	$\frac{L_{pp}}{80}$	$T_h = 0,5\sqrt{L_{pp}}$
Where L_{pp}, B as defined in *Pt 3, Ch 1, 6.2 Principal particulars* G_M transverse metacentric height of loaded craft, in metres $\theta = \left(0,45 + 0,1\frac{L_{pp}}{B}\right)\left(0,54 - \frac{L_{pp}}{1270}\right)$		

2.2.6 Dynamic loads in sailing conditions are to be determined from simulations or other established computation techniques. In the absence of this information, an allowance for dynamic loads by a multiplication factor of 1,33 on the combination of load by wind and own weight is to be taken.

2.3 Stress factors (SF)

2.3.1 The stress factors given in this Section are related to the Characteristic Failure Stress (CFS). The CFS is the stress at which, for the material loaded in the way it is loaded in the rig structure, the probability of breakage does not exceed 5 per cent.

2.3.2 Permissible stress is to be calculated using:

Permissible stress = SF * CFS

For composite materials, the CFS to be used for scantling calculation purposes is to be 90 per cent of the mean first ply/resin cracking failure determined from accepted mechanical tests, or the mean values minus two times the standard deviation of not less than 5 representative samples, whichever is the lesser. All test pieces are to be representative of the product to be manufactured and details of them are to be submitted for consideration.

2.3.3 Stress factors (SF) are related to modes of operation (seagoing, survival) and are given in *Table 7.2.2 Stress factors (SF) for seagoing and survival conditions*

Table 7.2.2 Stress factors (SF) for seagoing and survival conditions

Condition	Metal	Composite
Controlled condition during manufacture/ stepping/maintenance	0,80	0,33
Masts and spars in sailing condition	0,65	0,25
Masts and spars in survival condition	0,80	0,33

Standing rigging in sailing condition	0,53	0,27 (carbon) 0,37 (PBO)
Standing rigging in survival condition	0,68	0,34 (carbon) 0,47 (PBO)

Note 1. If a significant part of the load under consideration is a personnel load, then the stress factor is not to exceed 0,4 for metal or 0,17 for a composite material.

Note 2. For masts and spars, the stress factors are valid for both tensile and compression load types. Proposals to use a separate factor for compression will be subject to special consideration.

Note 3. Where an element is subjected to a combined load, such as bending and compression, this combination is also to be considered using $\frac{\sigma_b}{\sigma_y} + \frac{\sigma_a}{\sigma_c}$ Where:

σ_b is the bending stress in the mast section under consideration

σ_y is the tensile yield stress for the material

σ_a is the axial stress in the mast section under consideration

σ_c is the critical buckling for the mast section

Other materials will be specially considered. *See also Pt 3, Ch 7, 2.1 Modelling of the rig elements 2.1.3*.

Note 4. Stress factors for other sailing conditions are to be agreed with LR in the load case definition phase.

Note 5. For composite materials, *see Pt 8, Ch 1, 2.5 Materials data sheet*.

■ *Section 3*
Materials and components and arrangement

3.1 Materials

3.1.1 The materials used in the construction of the mast and spars are to be manufactured and tested in accordance with the appropriate requirements of the *Rules for the Manufacture, Testing and Certification of Materials, July 2021*

3.1.2 For composite materials, *see Pt 8, Ch 1, 2.5 Materials data sheet*.

3.1.3 Where stainless steel rigging is employed, particular attention is to be given to the selection of the grade of material used, as some stainless steels are prone to stress corrosion cracking and consequent fatigue failure, the onset of which is not readily observed. Suitable insulation is to be provided between differing materials to avoid galvanic corrosion.

3.2 Components

3.2.1 Components for rigs are to be manufactured, tested and documented in accordance with *Table 7.3.1 Summary of testing and associated documentation for rig components* under a suitable quality control system.

Table 7.3.1 Summary of testing and associated documentation for rig components

Part	Testing/inspection	Verification; final document to be issued
Mast and spreader tubes	Visual inspection	Materials properties certificate
Spars	Visual inspection	Materials properties certificate
Flettner rotor	Visual inspection	Materials properties certificate

Rigging wire and end connections	Break load testing	W - test certificate; or Type approval certificate
Rod and carbon rigging systems	Visual inspection	Type approval certificate
Loose items	Visual inspection	CE or other agreed standard
Key: W: witnessing by LR Surveyor		

3.3 Arrangement

3.3.1 Drainage is to be provided to prevent the build-up of seawater and condensation within the mast structure.

3.3.2 Where appropriate, rigs should be coated internally with a suitable preparation.

3.3.3 Openings in the masts for entry and exit of running rigging or cables should be adequately compensated with insert plates, doublers or patching.

3.3.4 Standing rigging is to be effectively attached to the mast, deck and hull structure and is to be so designed that it cannot become unintentionally disconnected during operation.

■ *Section 4*
Rig support

4.1 General

4.1.1 Assessment of rig support structures (e.g. mast step, chain plates, winch foundations and strong points) as outlined in this Section is part of the hull appraisal. The assessment is not part of the **RIGGING** or **RIGGING*** notations, but loads are to be considered in the design evaluation report of the TCF.

4.2 Support arrangements

4.2.1 Sailing yacht mast and standing rigging loadings and their support structure require special consideration as follows:

- Efficient integration of the mast into the hull.
- Adequate hull and deck longitudinal structure to resist hull bending.
- Provision of adequate transverse structure in way of masts, chainplates, keels, skegs etc.
- Provision of adequate bottom structure to support the mast and dissipate the mast loadings.
- Local reinforcement in way of chainplates, forestay and backstay fittings, etc.
- The deck and beams are to be suitably strengthened in way of masts, coachroof/deckhouse ends, windlass, cleats, sheet winches, sheet tracks etc. Where a mast is stepped on the deck or coachroof/deckhouse, the structural arrangements will be specially considered.

4.2.2 Details of the designer's/Builder's calculated maximum loads on the mast heel and the breaking loads of all standing rigging are to be submitted with the main structural plans for appraisal.

4.3 Bowsprits

4.3.1 The hull structure in way of the bowsprit is to be suitably reinforced with due account taken of the compressive loads along the bowsprit and bending moments due to rigging loads.

4.3.2 Details of the designer's/Builder's calculated maximum loads on the bowsprit and the breaking loads of all associated standing rigging are to be submitted with the main structural plans for appraisal.

4.4 Chainplates

4.4.1 Chainplates and other securing arrangements to take the loads of all standing rigging for masts and bowsprits, are to be of substantial construction and well integrated with the hull and/or deck supporting structure. They are to be of sufficient strength that, in the event of failure of the standing rigging, the watertight integrity of the hull is not impaired.

4.4.2 The breaking loads of all mast and bowsprit standing rigging, together with the actual loads imposed by the rigging, are to be submitted.

4.4.3 The minimum load to be applied to chainplates is the lesser of the breaking load or 2,5 times the maximum working load of the rigging. Each item of the supporting structure is to have a factor of safety applied as specified in *Table 7.4.1 Factors of safety for rig support items*.

Table 7.4.1 Factors of safety for rig support items

Item	Factor of safety
Lug, eyebolt eye	1,2
Lug to baseplate	1,2
Eyebolt/base to foundation	2,0
Chainplate to foundation (below decks)	2,0
Chainplate foundation to hull structure	2,0

■ *Section 5* Rig stepping

5.1 General

5.1.1 The rig dressing, i.e. dockside fitting of mast gear, and stepping, i.e. righting of the mast, is to be witnessed by an LR Surveyor.

5.1.2 The transport, stepping and tuning procedures are to be provided by the manufacturer.

5.2 Record of stepping

5.2.1 Two copies of the transport and stepping procedures with confirmation that the dressing and stepping was carried out under LR supervision is to be signed by the Surveyor and the Rigger. One copy is to be placed on board the vessel and the other submitted to LR.

5.2.2 The dock tuning procedure, i.e. step by step tightening of stays and jacking up of the mast, may be carried out without supervision of the Surveyor.

5.2.3 The initial pre-tension applied to the rig is to be measured and recorded for intermediate stages and the final state. These recorded values are to be included in the rig stepping report.

■ *Section 6* Rig behaviour trial

6.1 General

6.1.1 The rig behaviour at sea is to be witnessed by an LR Surveyor.

6.2 Rig behaviour

6.2.1 The expected behaviour of the rig when fitted to the vessel is defined by the manufacturer. The manufacturer is to provide predictions for key parameters such as heel angle, mast compression, loads in stays and loads on sheets for a range of weather conditions as may be encountered during the rig trial.

6.2.2 The rig behaviour trial is to include:

- 3 sailing conditions described in the rig operations manually, typically covering close hauled, reaching and running conditions.
- Transition between the sailing conditions.
- The process of setting, reefing and changing of sails in accordance with the procedure.

6.2.3 Observations made during trials are to focus on agreement between predicted condition and actual performance, as well as the transitions between conditions.

6.3 Record of trials

6.3.1 Two copies of the trial schedule and observed behaviour, signed by the Surveyor and Builder are to be provided on completion of the trial. Once copy is to be placed on board the vessel and the other submitted to LR.

Contents

Section

■ Section 1 Introduction

1.1 General

1.1.1 This Part of the Rules contains the particular requirements for the construction and classification of yachts with an overall length, L_{OA} (as defined in *Pt 3, Ch 1, 6.2 Principal particulars 6.2.4*), of 24 m or greater, where these differ from the general Rule requirements indicated in Parts 1 to 17.

1.1.2 The regulations for the construction, classification and Periodical Survey of yachts are given in *Pt 1 Regulations*.

1.1.3 The minimum requirements in respect of intact stability for yachts are indicated in *Pt 1, Ch 2, 1.1 General*.

1.1.4 Where a Load Line is to be assigned the yacht is to comply with the appropriate requirements of the National Authority or, in the absence of these, in accordance with the requirements of *Pt 4, Ch 2, 1 General* to *Pt 4, Ch 2, 6 Protection of openings* and *Pt 1, Ch 2, 1.1 General*.

1.1.5 The requirements for fire protection detection and extinction are to be in accordance with *Pt 17 Fire Protection, Detection and Extinction*.

1.1.6 Yachts may be the subject of National or International regulations concerning construction, safety and manning and compliance with these regulations is the responsibility of the Owners and Builders. Lloyds Register is able to advise on such matters and to issue applicable certificates where so authorised by the National Authority with which the yacht is registered.

1.1.7 A yacht may take any hull form and method of propulsion described in *Pt 1 Regulations* of these Rules. Other hull forms or methods of propulsion will be specially considered.

1.1.8 The scantling requirements for yachts constructed from steel, aluminium alloy and composite materials are given in *Pt 6 Hull Construction in Steel*, *Pt 7 Hull Construction in Aluminium* and *Pt 8 Hull Construction in Composite* respectively. Where it is proposed to construct a yacht in wood or other material not specifically covered by the Rules, such proposals will be subject to special consideration on the basis of the Rules.

1.2 Definitions

1.2.1 **Freeboard deck** is as defined in *Pt 3, Ch 1, 6.3 Freeboard deck 6.3.1*. When a lower continuous deck is designated as the freeboard deck, that part of the hull which extends above the freeboard deck is treated as superstructure so far as concerns the application of the conditions of assignment and the calculation of freeboard. It is from this lower continuous deck that the assigned freeboard is calculated.

1.2.2 **Virtual freeboard deck** is an imaginary continuous deck which, if fitted, would enable a freeboard, calculated in accordance with the Load Line requirements, and measured from the virtual freeboard deck, that would result in a draught not less than that corresponding to the assigned freeboard. That part of the enclosed hull which extends above the virtual freeboard deck may be treated as superstructure so far as concerns the application of the conditions of assignment provided it is not less than one standard superstructure height. (*See also Pt 3, Ch 2, 7.2 Definition of tiers*).

Section 2
International Rating Class (IRC) Yachts

2.1 General

2.1.1 The classification of International Rating Class Yachts will be specially considered on the basis of these Rules.

■ *Section 1*
General

1.1 Plans and data

1.1.1 Plans and data additional to those required by *Pt 3, Ch 1, 5 Information required* may be required to be submitted for appraisal, subject to the form of the yacht.

1.1.2 All plans are to be presented in a clear and unambiguous manner with sufficient details to avoid misinterpretation.

1.1.3 Unless otherwise specified, the requirements in this Chapter are based on yachts in Service Group 6 as defined in *Pt 1, Ch 2, 3.5 Service area restriction notations 3.5.5*. Where yachts have a service restriction, the requirements will be specially considered.

1.2 Scope

1.2.1 Unless specified otherwise, the requirements in this Chapter are for yachts in service group 6 as defined in *Pt 1, Ch 2, 3.5 Service area restriction notations 3.5.5* Special consideration may be given to yachts where service restrictions apply.

■ *Section 2*
Ship side valves

2.1 General

2.1.1 Ship side valves are generally to be in accordance with *Pt 15, Ch 2, 3 Shell valves and fittings (other than those on scuppers and sanitary discharges)*, but other materials may be considered.

2.1.2 Valves and sea chests are to be easily accessible and permanently marked. Valves not easily accessible are in addition to be fitted with remote control.

■ *Section 3*
Anchor stowage

3.1 General

3.1.1 Where anchors are mounted on stemhead fittings, suitable local sheathing or protection is to be provided in areas where the anchor can make contact with the hull or deck, further precautions are to be taken to minimise hull damage in the event of a collision. The fittings are to be of substantial construction and well secured to the hull and deck.

3.1.2 Details of stemhead fittings incorporating forestay attachments are to be submitted for approval.

■ *Section 4*
Bathing and watersport platforms and shell openings

4.1 General

4.1.1 Shell doors including bathing and watersport platforms, are generally to be fitted with a sill not less than 600 mm above the design waterline. All openings are to open into a watertight space with access into the yacht by watertight doors capable of being operated from both sides. The outer shell doors may be of a single or double leaf type with either hand or hand and hydraulic operated door clips to ensure watertightness when at sea. Any locking devices fitted are to `fail safe' in the event of hydraulic failure. Provision is to be made for doors to be closed and locked by hand in the event of hydraulic failure, *see Pt 3, Ch 4 Closing Arrangements and Outfit*.

4.1.2 Watertight boundaries behind shell openings with a sill height below, or less than 600 mm above, the design waterline are to have stress and deflection criteria required for watertight bulkheads by *Pt 6 Hull Construction in Steel*, *Pt 7 Hull Construction in Aluminium* and *Pt 8 Hull Construction in Composite* of the rules for steel, aluminium alloy and composite respectively with a design load according to side shell pressure, P_S as defined in *Pt 5, Ch 2, 4.2 Combined hydrostatic and hydrodynamic pressure on the shell plating*. Doors from this space providing internal access are to have a sill height at least 600 mm above the design waterline. The effect of flooding on stability and operational controls, and limitations on when and where opening may be used, are to be considered. Provision is to be made for hydraulic doors to be closed and locked by hand in the event of hydraulic failure, *see Pt 3, Ch 4 Closing Arrangements and Outfit*.

4.1.3 Drainage systems for the above shell openings are to be fitted with non-return valves.

4.1.4 Transom platforms are to be integral with the hull or be separate mechanically secured components.

4.1.5 Integral components are to have scantlings equivalent to the adjacent structure with care taken to ensure continuity of strength with no hard spots.

4.1.6 Separate mechanically secured components are to be of substantial construction and securely fastened to the main structure ensuring bolting and sealing arrangements are satisfactory with no hard spots.

4.1.7 Recesses for passerelles, windlasses, platforms, cockpits etc. are to be watertight and of equivalent strength to that of the surrounding hull and deck structure with care being taken to ensure continuity of strength. Electrical and hydraulic penetrations (where fitted) are to be through watertight glands. Direct overboard discharges are to be fitted to prevent any accumulation of water in the recess.

■ *Section 5*
Deck safety equipment

5.1 General

5.1.1 Sailing yachts are, in general, to be fitted with a pulpit, pushpit and guard wires with hand rails inboard to assist personnel movement around the upper deck. Motor yachts are, in general, to be fitted with bulwarks and/or guard rails.

5.1.2 The size, height and position of bulwarks, pulpit, pushpit and guard rails or wires and the securing points for handrails and lifelines are to be in accordance with National or International Standards, *see also Pt 4, Ch 2, 6.9 Bulwarks, guard rails and wires*. The scantlings and securing arrangements are to be designed to withstand the maximum load that could be exerted upon them in service, details of which are to be indicated in the relevant plans.

5.1.3 Doors fitted in bulwarks are to be of equal strength to the adjacent bulwarks and be capable of being secured closed at sea.

■ *Section 6* **Protection of openings**

6.1 General

6.1.1 Closing appliances for yachts are, in general, to provide weathertight integrity and safety equivalent to the requirements of *Pt 3, Ch 4 Closing Arrangements and Outfit* taking into consideration reductions depending on the height of the lowest weather deck, relative to the design waterline.

6.1.2 The vertical distance between the freeboard deck and the weather deck may be used to reduce the Load Line requirements for closing appliances, coaming heights and openings in the hull, superstructure and deckhouses.

6.1.3 The vertical distance between the virtual freeboard deck and the weather deck may be used to reduce the Load Line requirements for closing appliances, coaming heights and openings in the hull, superstructure and deckhouses.

6.1.4 Where this vertical distance (as defined in *Pt 4, Ch 2, 6.1 General 6.1.2* and *Pt 4, Ch 2, 6.1 General 6.1.3*) is at least one standard superstructure height then Load Line requirements for closing appliances, coaming heights and openings apply as if an additional tier of superstructure existed. *See also Pt 3, Ch 2, 7.2 Definition of tiers 7.2.2*.

6.1.5 Where this vertical distance (defined in *Pt 4, Ch 2, 6.1 General 6.1.2* and *Pt 4, Ch 2, 6.1 General 6.1.3*) is less than one standard superstructure height the coaming heights of doors, hatches, ventilators, air pipes, etc. may be reduced in proportion to the ratio of the actual distance and one standard superstructure height.

6.2 Hinged weathertight doors

6.2.1 Doors on the weather deck (first tier accommodation) protecting direct access to machinery spaces are to be of substantial construction in accordance with or equivalent to recognised National or International Standards. They are to be permanently attached to the casing, outward opening and gasketted weathertight with a minimum of six clips and have a coaming height of 460 mm with a minimum of 230 mm depending on the excess freeboard.

6.2.2 Doors on the weather deck to first tier accommodation or other spaces protecting access below are to be as required by *Pt 4, Ch 2, 6.2 Hinged weathertight doors 6.2.1* with a minimum of four clips. Provided access to the space(s) may be obtained from the deck above, the coaming height may be 230 mm with a minimum of 150 mm depending on the excess freeboard.

6.2.3 Where wood doors are proposed on the weather deck in lieu of doors in *Pt 4, Ch 2, 6.2 Hinged weathertight doors 6.2.2* above they are to be strongly constructed of hardwood not less than 50 mm thick, double gasketted with coamings as required by *Pt 4, Ch 2, 6.2 Hinged weathertight doors 6.2.2*. For doors in exposed locations additional securing arrangements by slip bolts, clamps or equivalent are required. These doors are not to be the sole means of entry or exit from the space. Where these doors may be required to be used as a means of escape in an emergency situation, the additional securing arrangements are to be operable from both sides.

6.2.4 The use of FRP for doors on the weather deck other than to machinery spaces may be accepted, providing the doors are of substantial construction in accordance with *Pt 4, Ch 2, 6.2 Hinged weathertight doors 6.2.2*.

6.2.5 Proposals to use FRP doors for access to machinery spaces are to comply with *Pt 4, Ch 2, 6.2 Hinged weathertight doors 6.2.4* in addition to *Pt 17 Fire Protection, Detection and Extinction*, in respect of fire requirements and compliance with any National Authority requirements which may be applicable.

6.2.6 Doors in the second tier accommodation are to be as indicated in *Pt 4, Ch 2, 6.2 Hinged weathertight doors 6.2.1* with a minimum of four clips, or wood doors per *Pt 4, Ch 2, 6.2 Hinged weathertight doors 6.2.3* and have a coaming height of 100 mm with a minimum of 50 mm depending on the excess freeboard. Sliding doors with equivalent securing arrangements may be accepted.

6.3 Hatches (coamings and covers)

6.3.1 Hatches on the weather deck and deck above are to have a structural integrity of not less than the structure to which they are fitted and are to be weathertight when closed.

6.3.2 Hatches on the weather deck in the forward 0,25L_L or to machinery spaces are to be hinged on the forward side and have 460 mm coamings with a minimum of 230 mm depending on the excess freeboard.

6.3.3 Elsewhere on the weather deck, hatches which are proposed to be open at sea and provide access to lower accommodation spaces are to have a coaming height of 230 mm with a minimum of 150 mm depending on the excess freeboard.

6.3.4 Hatches on the deck above the weather deck which are proposed to be open at sea, are to have a coaming height of 150 mm with a minimum of 50 mm depending on the excess freeboard.

6.3.5 Flush hatches that are not closed by gasketed covers and secured by closely spaced bolts will be specially considered but should not, in general, be fitted on the weather deck. However, flush hatches fitted with drains led overboard that do not require to be opened at sea will be considered. Flush hatches are to be watertight and satisfactorily prototype tested at design head. Flush hatches are to be kept closed at sea. A spare gasket is to be provided on board.

6.3.6 To facilitate a swift and safe means of escape to the lifeboat and life raft embarkation deck, the following provisions apply to overhead hatches fitted along the escape routes addressed by *Regulation 13 - Means of escape*:

(a) escape hatches and their securing devices are to be of a type which can be opened from both sides;
(b) the maximum force needed to open the hatch cover is not to exceed 150 N; and
(c) the use of a spring counterbalance, equalising or any other suitable device on the hinge side to reduce the force needed for opening is acceptable.

6.4 Ventilators and air pipes

6.4.1 Ventilators and air pipes are to have coamings complying with *Pt 3, Ch 4, 11 Ventilators* and *Pt 15, Ch 2, 11 Air, overflow and sounding pipes* respectively.

6.4.2 Where necessary for operational reasons, coamings on the weather deck protected by the bulwark may be reduced to the bulwark height subject to a minimum coaming height of 450 mm for ventilators and 300 mm for air pipes.

6.5 Portlights, windows and skylights

6.5.1 Special arrangements in accordance with a relevant National or International Standard may be accepted in lieu of arrangements in accordance with the requirements of this Section.

6.5.2 The requirements for portlights, windows and skylights are indicated in *Pt 3, Ch 4 Closing Arrangements and Outfit*. Proposals to fit windows below freeboard deck will be specially considered.

6.5.3 Round, elliptical or elongated portlights are to have a structural integrity of not less than the structure to which they are fitted. If fitted below the weatherdeck, they are to be provided with permanently attached deadlights. *See also Pt 3, Ch 4, 7.12 Deadlights and storm covers 7.12.2*.

6.5.4 Where internal covers are provided, they are to be gasketted and capable of being secured weathertight (with additional backing bars if necessary). Provision is to be made for the storm covers to be stored on board and their stowage location noted in the document `For the information of the Master'. Internal storm blinds may be accepted subject to satisfactory tests being carried out.

6.5.5 Laminated glass is to be in accordance with *Pt 3, Ch 4, 7.9 Laminated glass thickness*. Laminated glass may include chemically toughened glass (CTG), thermally toughened safety glass (TTG) or heat strengthened glass (HSG). *See also Pt 3, Ch 4, 7.10 Other glazing materials*. The glass is to be in accordance with a recognised International Standard, e.g. ISO 11336 (Parts 1 to 3).

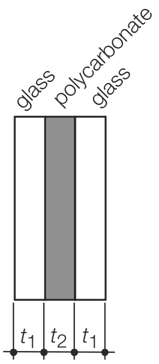
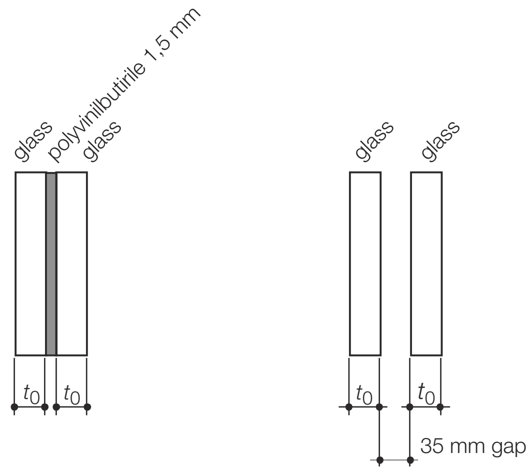
6.5.6 Wheelhouse windows are to be of toughened safety glass or of laminated construction.

6.5.7 Details of the attachment of windows in their frames and of frames to the yacht structure are to be submitted for approval.

6.5.8 Storm covers or deadlights are required for all windows and portlights fitted in the front and sides of deckhouses on the weather deck and for front windows fitted on the second tier. Where storm covers are interchangeable port and starboard, a sufficient number to fit any one side is to be provided.

6.5.9 A glazing equivalent may be fitted in lieu of deadlights or stormcovers on the weather deck and above. The thicknesses and arrangements are to be acceptable to the National Authority with whom the craft is registered and/or by the Administration within whose jurisdiction the ship is intended to operate. For arrangements of glazing acceptable to Lloyds Register (hereinafter referred to as LR), *see Table 2.6.1 Acceptable arrangements of glazing in lieu of portable storm covers/deadlights*. Alternative arrangements of glazing in lieu of deadlights or storm covers may be accepted provided details are submitted for consideration.

Table 2.6.1 Acceptable arrangements of glazing in lieu of portable storm covers/deadlights

In lieu of portable storm covers	In lieu of deadlights or storm covers
 $t_1^2 + (0{,}77t_2)^2 + t_1^2 = (1{,}2t_0)^2$	
Symbols	
t_0 = minimum thickness of toughened glass as calculated in *Pt 3, Ch 4, 7.8 Toughened safety glass thickness 7.8.1*	

6.6 Sliding glass doors or glass walls

6.6.1 Special arrangements in accordance with a relevant National or International Standard may be accepted in lieu of arrangements in accordance with the requirements of this Section.

6.6.2 When sliding glass doors are provided, or a glass wall which includes an access, an alternative access, or exit from the space, is to be provided, and the arrangements are to be in accordance with approved plans and weathertight commensurate with their position. Coaming heights are, in general, to be in accordance with *Pt 4, Ch 2, 6.2 Hinged weathertight doors* and the use of portable coamings will be considered. Details are to be submitted.

6.6.3 The glass used in the above is to be toughened safety glass or equivalent in accordance with *Pt 4, Ch 2, 6.5 Portlights, windows and skylights*.

6.6.4 Storm covers of strong construction are to be provided and stored on board. Aft facing glass doors or walls in the second tier and above, are not required to be fitted with storm protection. The use of a virtual freeboard deck to determine storm cover requirements is not permitted. Additional portable supports are to be provided as necessary and full details are to be submitted for approval. Roller shutters or other alternatives will be specially considered.

6.6.5 In lieu of a weathertight coaming for the cover, adequate drainage is to be provided between the cover and the glass which may be in the form of a sump drained overboard, with a grating over, details of such proposals should be submitted for individual consideration.

6.7 Scuppers and sanitary discharges

6.7.1 Piping and valves are, in general, to comply with the requirements indicated in *Pt 15, Ch 2, 3 Shell valves and fittings (other than those on scuppers and sanitary discharges)*.

6.8 Freeing ports

6.8.1 In general, freeing ports are to be in accordance with the requirements indicated in *Pt 3, Ch 4 Closing Arrangements and Outfit*, taking into consideration the position of the virtual freeboard deck indicated in *Pt 4, Ch 2, 6.1 General*.

6.9 Bulwarks, guard rails and wires

6.9.1 Bulwarks, guard rails and wires are, in general, to comply with the requirements indicated in *Pt 3, Ch 4, 8 Bulwarks, guard rails and other means for the protection of crew*.

6.9.2 Where a bulwark of reduced height is fitted, guard rails or wires are to be provided above the bulwark to a height of 1000 mm above the deck.

6.9.3 Where the proper working of a yacht may otherwise be impeded bulwarks, guard rails of wires of a reduced height may be considered. Details are to be submitted for approval.

6.9.4 Protection is to be provided in way of boats, liferafts etc.

■ *Section 7* Corrosion protection

7.1 General

7.1.1 Corrosion prevention and coatings requirements are to be in accordance with *Ch 15 Corrosion Prevention* of the Rules for Materials.

7.1.2 The design of the structure and methods of attachment of fittings are to take into consideration procedures to minimise corrosion of metal structures and fittings due to electro-chemical action. All exposed steel and aluminium alloy surfaces are to be protected by the application of a suitable paint and anti-fouling system and the fitting of a cathodic or impressed current cathodic protection (ICCP) system.

7.1.3 Sacrificial anodes are to be mounted equidistant between metals being protected, and their location and attachment are to be such as to minimise the effects of welding on the hull materials.

7.1.4 Anodes with cast-in galvanised steel straps are to be secured to the steel hull by welded studs or direct welding.

7.1.5 The design and performance characteristics of the cathodic protection system are the Builder's responsibility. Particular attention is to be given to the earth bonding system, to provide good electrical continuity.

7.1.6 Yachts fitted with a negatively grounded electrical system or fitted with a negatively grounded independent battery system may use the impressed current cathodic protection (ICCP) system.

7.2 Protection - Aluminium alloy yachts

7.2.1 Anti-fouling paints containing copper are not to be used.

7.2.2 Bilges and internal surfaces subject to salt laden air are to be coated with a waterproof mastic or equivalent.

7.2.3 Particular attention is to be given to the design and selection of materials used for underwater fittings and the associated piping systems to limit the effect of bimetallic corrosion. Where materials other than aluminium are used they are, in general, to be electrically insulated from the hull and internal metal piping or cathodically protected separately by anodes attached directly to such fittings.

7.3 Protection - Composite yachts

7.3.1 Aluminium alloy or steel sterndrives, waterjet units and trimtabs are to be cathodically protected by anodes mounted on the hull, direct to the unit being protected or through the bonding system.

7.4 Protective coating systems in dedicated seawater ballast tanks – ShipRight Notations ACS(B)

7.4.1 For ships that are required to comply with IMO *Resolution MSC.215(82) - Performance Standard for Protective Coatings for Dedicated Seawater Ballast Tanks in all Types of Ships and Double-Side Skin Spaces of Bulk Carriers - (Adopted on 8 December 2006)*, all dedicated seawater ballast tanks are to have approved coating systems applied in accordance with LR's ShipRight Procedure *Anti-Corrosion System Notation*.

7.4.2 **ShipRight ACS(B)** will be entered in Column 4 of the *Register Book* to indicate that the seawater ballast tanks are coated with approved coating systems in accordance with IMO *Resolution MSC.215(82) - Performance Standard for Protective*

Coatings for Dedicated Seawater Ballast Tanks in all Types of Ships and Double-Side Skin Spaces of Bulk Carriers - (Adopted on 8 December 2006)

Section 8
Navigation in first-year ice conditions

8.1 General

8.1.1 Where an ice class notation is to be included in the class of a craft, the scantlings will require special consideration, *see Pt 3, Ch 2, 9 Navigation in ice*.

8.1.2 Yachts in Service Group G6, which have their own propulsion machinery, and which are built of steel but are not strengthened for navigation in ice, may be eligible for assignment of Finnish-Swedish Ice-Due Class II under the Finnish and Swedish Boards of Navigation *Finnish-Swedish Ice Class Rules*. Yachts in Service Groups G1–G4 inclusive, constructed in any material, together with Yachts in Service Group G6 constructed in aluminium or composites are not eligible for this notation.

Section 9
Yacht support vessel

9.1 General

9.1.1 A **yacht support vessel** provides support to a yacht and may often also be referred to as a ‘shadow yacht’. The yacht support vessel may be provided with an extensive range of equipment and facilities to perform these duties, such as small craft, seaplanes, large galleys and waste management systems.

9.1.2 For yacht support vessels, the following are also to be considered according to the load line requirements:

(a) Sill heights of door openings;
(b) Windows and portlights;
(c) Freeing port areas; and
(d) Sill heights of ventilators.

■ *Section 1* Hull design and construction parameters

1.1 Plans and data

1.1.1 In addition to the general plans and data required by *Pt 3, Ch 1, 5 Information required* the following details of additional structural components, particular to sailing yachts, are to be submitted for appraisal:

- Sail plan, including sail set configurations.
- Limit load and working load on mast foundation.
- Mast loadings.
- Bowsprit arrangement with all its stays and loadings.
- Rigging loadings.
- Mast step.
- Mast partners.
- Boom and gaff.
- Mast bearing integration and its foundation in the case of aerorig/dynarig.
- Ballast keel lines plan.
- Ballast keel securing arrangements including information of the weight of the keel and ballast and its centre of gravity.
- Keel trunk in the case of a lifting keel or canting keel.
- Dagger board arrangement.
- Rudder skeg construction and support details.
- Chainplates, Furler, forestay and backstay attachments.
- Deck hardware plan.
- Deck fitting for cleats, sheet winches, sheet tracks, travellers etc.
- Through-deck fittings.
- Mast and spreader sections.

1.1.2 All plans are to be presented in a clear and unambiguous manner with sufficient details to avoid misinterpretation.

1.2 Mast and rigging support arrangements

1.2.1 Sailing yacht mast and standing rigging loadings and their support structure require special consideration as follows:

(a) Adequate hull and deck longitudinal structure to resist hull bending.
(b) Provision of adequate transverse structure in way of masts, chainplates, keels, skegs etc.
(c) Provision of adequate bottom structure to support the mast and dissipate the mast loadings.

(d) Local reinforcement as given in *Pt 8, Ch 3, 3.14 Local reinforcement* in way of chainplates, forestay and backstay fittings, etc.

(e) The deck and beams are to be suitably strengthened in way of masts, coachroof/deckhouse ends, windlass, cleats, sheet winches, sheet tracks etc. Where a mast is stepped on the deck or coachroof/deckhouse the structural arrangements will be specially considered.

1.2.2 Details of the designer's/Builder's calculated maximum loads on the mast heel and the breaking loads of all standing rigging are to be submitted with the main structural plans for appraisal.

1.3 Bowsprits

1.3.1 The hull structure in way of the bowsprit is to be suitably reinforced with due account taken of the compressive loads along the bowsprit and bending moments due to rigging loads.

1.3.2 Details of the designer's/Builder's calculated maximum loads on the bowsprit and the breaking loads of all associated standing rigging are to be submitted with the structural plans for appraisal.

■ *Section 2*
Hull construction

2.1 Hull scantlings (composite materials)

2.1.1 The basic structural scantlings are, unless specified within this Section, to be as indicated in *Pt 8 Hull Construction in Composite*.

2.1.2 The shell weight/thickness determined from *Pt 8 Hull Construction in Composite*, is to be maintained throughout the length of the craft, with the bottom shell weight extending to the chine line or 150 mm above the static load waterline, whichever is the greater.

2.1.3 The keel plate thickness for sailing yachts is to be 1,1 times the keel thickness for motor craft as determined in *Pt 8 Hull Construction in Composite*. In no case is the thickness of keel to be taken less than the thickness of the adjacent bottom shell or fin and tuck as appropriate.

2.1.4 The fin and tuck thickness is not to be less than 0,9 times the keel thickness for motor craft as determined in *Pt 8 Hull Construction in Composite*. In no case is the thickness of the fin and tuck to be taken less than the thickness of the adjacent bottom shell.

2.1.5 The construction of hull to deck connections is to be in accordance with *Pt 8, Ch 2, 5 Details and fastenings*.

2.1.6 The hull laminate is to be strengthened in way of the attachment of chainplates etc. *See Pt 8, Ch 2, 5 Details and fastenings*.

2.1.7 The stern or transom is to be the same weight as the side shell and is to be adequately stiffened with special consideration being given to the transmission of backstay loadings.

2.1.8 Where twin bilge keels are fitted, the bottom laminate in way of the bilge keels is to be formed by extending the keel reinforcement to a distance not less than 25 per cent the width of the keel, as required by *Pt 8 Hull Construction in Composite*, outside the line of the outboard edge of the bilge keels or to the supporting structure whichever is the greater, prior to being tapered in accordance with the Rules to the adjacent bottom shell laminate. *See also Pt 4, Ch 3, 2.1 Hull scantlings (composite materials) 2.1.10*.

2.1.9 The hull and deck are to be locally increased in thickness in way of fittings for rudder tubes, propeller brackets etc. The increase is not to be less than 50 per cent of the adjacent plate laminate. Details of such reinforced areas are to be submitted for consideration.

2.1.10 Local reinforcement is, in general, to extend under the adjacent supporting structure and then be tapered gradually to the base laminate thickness in accordance with *Pt 8, Ch 3, 3.14 Local reinforcement*.

2.2 Transversely framed yachts

2.2.1 Sailing yachts with a conventional rig, are to be provided with suitably increased scantlings in floors, frames, beams and brackets adjacent to each mast.

2.2.2 In general, beams at the heads of web frames and four beams in way of each mast in sailing and auxiliary yachts are to have their scantlings increased by a factor of two. Where practicable, masts are to be located in way of transverse bulkheads or other primary stiffening.

2.2.3 Keel mounted masts are to be mounted on a suitable mast step secured to three floors at a height sufficient to provide the necessary structural integrity and to keep the heel of the mast clear of any bilge water.

2.2.4 Keel mounted masts are to be fitted with mast partners running fore and aft on either side of the mast to join the transverse beams. The strength of the mast partners is to be the same as for the beams.

2.2.5 Deck mounted masts are to be housed in a mast step positioned directly over a bulkhead or a web frame/deep beams with a pillar fitted under the mast.

2.3 Longitudinally framed yachts

2.3.1 Conventional masts mounted on mast steps as in *Pt 4, Ch 3, 2.2 Transversely framed yachts 2.2.3* are to be fitted with heavy transverse web frames as required by *Pt 4, Ch 3, 2.2 Transversely framed yachts 2.2.2*.

2.4 Yachts fitted with non-conventional rigs

2.4.1 The structure in way of non-conventional mast configurations will be specially considered.

■ *Section 3*
Chain plates

3.1 General

3.1.1 Chain plates and other securing arrangements to take the loads of all standing rigging for masts and bowsprits, are to be of substantial construction and well integrated with the hull and/or deck supporting structure. They are to be of sufficient strength that, in the event of failure of the standing rigging, the watertight integrity of the hull is not impaired.

3.1.2 The breaking loads of all mast and bowsprit standing rigging together with the actual loads imposed by the rigging are to be submitted.

3.2 Calculations

3.2.1 The strength of any part of chainplates or structure to which it is attached is not to be less than the breaking load of the rigging to which it is attached or 2,5 times the maximum working load of the rigging, whichever is the lesser and to that load subject to the following factors of safety (FOS)

Items:	Minimum FOS:
Rigging	1,0
Lug, eyebolt eye	1,2
Lug to baseplate	1,2
Eyebolt/base plate to foundation	2,0
Chainplate to foundation (below decks)	2,0
Chainplate foundation to hull structure	2,0

■ *Section 4*
Deck planking

4.1 General

4.1.1 The construction of decks of steel, aluminium alloy or composite materials is to be in accordance with *Pt 6, Ch 3, 8 Deck structures*, *Pt 7, Ch 3, 8 Deck structures* and *Pt 8, Ch 3, 8 Deck Structures* respectively. Wood deck sheathing is in general to be treated as cosmetic and is outside the scope of these Rules. However, any wood sheathing fitted is not to be detrimental to the integrity of the main deck structure. Details of the means of attachment of such wood sheathing are to be submitted for consideration.

4.1.2 Decks constructed of wood will be specially considered on the basis of the Rules.

■ *Section 5*
Deck fittings

5.1 General

5.1.1 Due consideration is to be given at the design stage to ensure that additional structural support, by way of pads, brackets etc. is provided in way of deck fittings such as mainsheet and genoa tracks, winches, eyebolts, sail-lead tracks, fairleads, anchor and chain cable handling and securing arrangements, grab rails, guard wires, hatch hinges etc. which are subject to substantial loadings and or use.

5.1.2 Fittings which are subject to significant loads are, in general, to be through bolted, in single skin areas. The laminate is to be locally increased in thickness as necessary with due account taken of such loadings.

5.1.3 Details of inserts, local reinforcement and through bolting arrangements for yachts of composite construction are to be in accordance with *Pt 8, Ch 2 Construction Procedures* and *Pt 8, Ch 3 Scantling Determination for Mono-Hull Craft*.

■ *Section 6*
Ballast keels

6.1 External ballast keel

6.1.1 The ballast keel may be of lead, cast iron or other suitable material. Cast iron or other ferrous metals are not to be used in wood or composite craft sheathed with copper or other non ferrous metal.

6.1.2 Prior to installation the ballast keel is to be `Dry fitted' to the hull and the top is to be smooth, or slightly concaved in all directions, and well coated with a suitable bedding compound.

6.1.3 In composite yachts care is to be taken to prevent crushing of GRP laminates through overtightening of keel bolts.

6.1.4 A substantial plate washer is to be fitted under the head of the keel bolt. The diameter and thickness are to be not less than 4,0 and 0,25 times the bolt diameter, respectively, but the thickness need not in general exceed 8 mm. The top of the bolt is to have sufficient thread to take double nuts or other suitable locking arrangement. *See also Pt 4, Ch 3, 6.3 Keel bolts 6.3.6*.

6.1.5 The structure in way of the ballast keel is to be in accordance with the requirements of *Pt 6 Hull Construction in Steel*, *Pt 7 Hull Construction in Aluminium* and *Pt 8 Hull Construction in Composite* for the respective material.

6.1.6 In steel/aluminium alloy yachts all bottom structure in way of the ballast keel(s) is to be welded by means of double continuous welding.

6.1.7 Ballast keels are to be fully supported by floors to distribute the keel loadings to the bottom structure, *see Pt 8, Ch 3 Scantling Determination for Mono-Hull Craft*. The scantlings of the floors and frames will be specially considered in conjunction with the keel mass together with the size, material and position of the keel bolts.

6.1.8 Canards and lifting keels are outside the scope of the Rules but the structure in way will be specially considered with regard to maintenance of structural and watertight integrity. Full details are to be submitted for appraisal.

6.2 Internal ballast keel

6.2.1 Where ballast is to be incorporated in the keel, the internal surface is to be suitably coated prior to filling, and on completion the top surface is to be sealed.

6.2.2 For steel and aluminium alloy yachts the method of installing the internal ballast is not to be detrimental to the plating or internal structure. Details of the installation procedure are to be submitted for consideration prior to implementation.

6.2.3 Internal ballast is to be suitably supported and secured against movement. The supporting structure in way of internal ballast is to be suitably increased in strength.

6.2.4 In steel/aluminium yachts, the ballast is to be totally encapsulated by fully welded plating with a minimum thickness of 6 mm. Alternative arrangements will be specially considered.

6.2.5 In composite yachts, the internal ballast is to be encapsulated by a laminate equivalent in thickness to half the rule bottom shell laminate or 2400g/m^2 CSM (or equivalent), whichever is the greater.

6.3 Keel bolts

6.3.1 The keel bolts are to be of a corrosion resistant material. The nuts, washers etc. are to be of a material the same as, or compatible with, that of the keel bolts. The specifications of these materials are to be submitted for appraisal.

6.3.2 The diameter of keel bolts, d_k, is to be that determined from the following formula, or 14 mm, whichever is the greater:

$$d_k = 14,2\sqrt{\frac{w d_{cg}}{\sigma_u b_k}} \text{ mm}$$

where

w = the portion of the weight of ballast keel supported by the bolt, in kg

d_{cg} = vertical distance of the centre of gravity of weight, w, below top of ballast keel, in mm

b_k = breadth of top of ballast keel in way of bolt, in mm

σ_u = ultimate tensile strength of the bolt material, in N/mm^2

When determining w for the bolt at the ends of the keel, the weight of any overhang is to be included.

6.3.3 Where double bolts are to be fitted, the total cross-sectional area of the bolts is to be not less than 1,2 times the cross-sectional area of the bolt determined in accordance with *Pt 4, Ch 3, 6.3 Keel bolts 6.3.2*.

6.3.4 Keel bolts are to be fitted alternately on opposite sides of the middle line, and as close as is practicable to the bottom floor structure.

6.3.5 The ballast keel is to be secured by through bolting, but where this is not practicable, short keel bolts or studs may be fitted.

6.3.6 A substantial plate washer is to be fitted under the head of the keel bolt. The diameter and thickness are to be not less than 4,0 and 0,25 times the bolt diameter, respectively, but the thickness need not exceed 8 mm. Washer plates, where square or rectangular, are to have suitably radiused corners. In composite and wood craft the washer plates are to have all edges dressed smooth in addition to being suitably radiused.

6.3.7 The bottoms of short keel bolts are to be secured by nuts and washers fitted in pockets in the keel, or by square plate nuts cast in with the keel. Where cast in, the square plate nuts are to have a breadth and depth not less than 3,0 and 1,0 times the bolt diameter, respectively.

6.3.8 Where studs are fitted, the length of the threaded portion into the cast iron or steel keel is to be not less than 1,5 or 2,5 times the stud diameter where through tapped or blind tapped respectively.

6.3.9 It is recommended that the design of the keel bolt is such that it can be withdrawn for survey and is not cast permanently into the ballast keel.

6.3.10 Details of the proposed torque to be applied to the keel bolts are to be indicated on the relevant plans and submitted.

Section 7
Rudder skegs and rudders

7.1 Skegs

7.1.1 Skegs are to be effectively integrated into the adjacent structure and their design is to be such as to facilitate this.

7.1.2 The scantlings of skegs are to be sufficient to withstand any docking forces that they may be subjected to.

7.1.3 The thickness of the skeg plating is in no case to be taken as less than 1,5 times the thickness of the adjacent bottom shell or the fin and tuck laminate whichever is the greater.

7.1.4 Where metallic sub-frames are laminated into skegs, providing transverse stiffening to the skeg and support for the rudder pintle, such stiffening members are to be fully integrated with hull framing to ensure continuity of strength.

7.1.5 The scantlings of skegs of composite construction will be specially considered on the basis of the Rules, and in this respect are to be of equivalent strength and load carrying capability to that required for skegs of steel construction from *Pt 3, Ch 3, 3.3 Rudder horns*. Due account is to be taken of the differing material properties.

7.1.6 Direct calculations may be used as an alternative to the requirements of *Pt 4, Ch 3, 7.1 Skegs 7.1.5* to determine the scantlings of composite skegs. Such calculations are to be submitted for appraisal.

7.2 Rudder construction arrangements

7.2.1 Rudder construction for sailing yachts is generally to be in accordance with *Pt 3, Ch 3, 2 Rudders*.

7.2.2 For use in the determination of the rudder stock diameter, within *Table 3.2.6 Rudder stock diameter*, the factor f_{c} may be taken as 70 for yachts with an overall length, L_{OA}, of 24 m varying up to 79 at a length of 50 m. Intermediate values are to be determined by linear interpolation. Yachts with a length, L_{R}, in excess of 50 m are to comply with *Table 3.2.6 Rudder stock diameter*.

7.2.3 The rudder stock diameter is to be based upon the maximum stated operational speed of the yacht, but in no case is this to be taken less than $2,536\sqrt{L_{\text{WL}}}$ knots. L_{WL} is as defined in *Pt 3, Ch 1, 6.2 Principal particulars 6.2.5*.

Section 8
Open cockpits and companionways

8.1 Cockpit construction

8.1.1 Cockpits are to be of watertight construction with scantlings equivalent to that of the upper deck.

8.1.2 Cockpit lockers and hatches where fitted, are to be of substantial construction and are to be tested weathertight.

8.1.3 Where engine removal or other hatches are fitted in the cockpit sole they are to be watertight and bolted down. Detailed plans are to be submitted for approval.

8.1.4 The height of the cockpit sole above the waterline is to be such that the water will effectively drain overboard under all normal conditions of heel and trim.

8.2 Companionways

8.2.1 Companionway openings, are to be sited on, or as close as possible to, the centreline. Sill heights are to be not less than as required by *Pt 3, Ch 4 Closing Arrangements and Outfit*.

8.2.2 Companionway hatches are to be of substantial construction capable of being opened from both sides and be tested weathertight.

Section 9
Anchoring and mooring equipment

9.1 General

9.1.1 The requirements of *Pt 3, Ch 5 Anchoring and Mooring Equipment* apply to fore and aft rigged sailing yachts of all sizes.

9.1.2 Sailing yachts with three or more masts and fitted with a square rig are to be fitted with anchors 25 per cent heavier than those calculated in accordance with *Pt 3, Ch 5 Anchoring and Mooring Equipment*. Chain cable, hawsers and warps are to be increased accordingly.

9.1.3 Square rigged yachts are to have a full length of chain cable on the main anchor but may have rope with a chain tail fitted to the second anchor. Kedge anchors may be fitted using the rule length and size of warp without a chain tail.

Contents

Section 1
Rule application

1.1 General

1.1.1 The global and local load and design criteria detailed in this Part are to be used in conjunction with the formulae given in *Pt 6 Hull Construction in Steel*, *Pt 7 Hull Construction in Aluminium* and *Pt 8 Hull Construction in Composite* to determine the scantlings of steel, aluminium alloy and composite craft respectively as defined in *Pt 1 Regulations*.

1.1.2 The global load and design criteria given in this Part are provided to enable the designer/Builder to check global hull strength against ductile failure modes involving gross deformation. The strength calculations are, in general, to be conducted using finite element analysis techniques with a three dimensional model.

1.1.3 Load and design criteria detailed in this Part are to be supplemented by direct calculation methods incorporating model test results and numerical analysis for novel designs. Full scale measurements may be required where considered necessary by Lloyds Register (hereinafter referred to as LR).

1.1.4 Where an operational envelope is assigned it will be based on the allowable speeds, significant wave heights and corresponding displacements. Installation of an accelerometer at the LCG with a visual display in the wheelhouse may be required.

1.1.5 The operational envelope assigned is based on the assumption that the wave height can be visually observed. Where this is not the case, the speed of the craft is to be suitably reduced.

1.1.6 The design assessment is to include a range of speeds covering all modes of operation for which the craft is designed, i.e. speeds corresponding to displacement, semi planing and fully planing. A craft which is designed to operate in the planing mode will need to be assessed using the requirements of *Pt 5, Ch 3 Local Design Criteria for Craft Operating in Non-Displacement Mode* at its design speed and required significant wave height, as well as the requirements of *Pt 5, Ch 4 Local Design Criteria for Craft Operating in Displacement Mode* when operating at reduced speed and a more severe wave height.

1.1.7 The load design criteria given in this Part are dependent on the operating mode of the craft as follows:

- Craft operating in the **non-displacement** mode:
  - Applies to craft operating in full planing or semi planing modes.
  - Applies to craft in foil borne mode.
  - Applies to craft where other lifting devices are actively supporting some or all of the craft's weight.
  - Typically this applies to craft with a Taylor Quotient, Γ , greater than 3. Γ is defined in *Pt 5, Ch 2, 2.1 Parameters to be used for the determination of load and design criteria 2.1.17*. However, the following is to be noted:
    - Some craft are not designed to plane, but have Γ greater than 3, e.g. SWATHs, fast displacement yachts, wave piercing and low wash catamarans. These craft are to be considered as only operating in the displacement mode.
    - Some craft are designed to plane with Γ less than 3 and these should be considered as operating in the non-displacement mode.
- Craft operating in the **displacement** mode:
  - Applies to craft designed to operate in the displacement mode.
  - Applies to all other craft where they are not operating in the non-displacement mode, e.g. at lower speed in severe weather.

■ *Section 2*
Direct calculations

2.1 General

2.1.1 Where the designer intends to submit direct calculations, it is the responsibility of the designer to ensure at an early stage that the proposed method and calculations are acceptable to LR. The case for direct calculations is to be supported by the following:

- goal of the requirement;
- reference(s) to published work supporting the proposed method; and
- acceptance criteria.

2.1.2 Direct calculations using hydrodynamic computer programs may be specifically required by the Rules. Also they may be required for craft having novel design features, or may be submitted in support of alternative load and design criteria. LR may, when requested, undertake calculations on behalf of designers and make recommendations in regard to suitability of any required model tests.

2.2 Submission of direct calculations

2.2.1 In cases where direct calculations have been carried out, the following supporting information is to be submitted as applicable:

(a) Reference to the direct calculation procedure and technical program used.
(b) Input data.
(c) A description of the model.
(d) A summary of analysis parameters including environmental conditions, speeds and headings.
(e) Details of the weight distributions.
(f) A comprehensive summary of calculation results. Sample calculations are to be submitted where appropriate.

2.2.2 In general, all input data and output results are required to be submitted. In such cases, magnetic media with agreed format may be used for submission.

2.2.3 The responsibility for error free specification and input of program data and the subsequent correct transposal of output rests with the designer/Builder.

■ *Section 3*
Model experiments

3.1 General

3.1.1 Model experiments and theoretical calculations may be required to be carried out for new design concepts and the results are to be provided when plans are submitted for approval.

3.1.2 Where model testing is undertaken, the following details are to be submitted:

(a) A summary of the model construction and its instrumentation, including calibration of instruments.
(b) A summary of the testing arrangements and procedures.
(c) A summary of the tank facilities and test equipment.
(d) Details of the wave generation, response measurements, definitions and notations.
(e) Details of data recording, reduction and data analysis procedures.
(f) Details of calibration procedures with theoretical computations.
(g) Tabulated and plotted output.

3.2 Model test matrix

3.2.1 Where model testing is undertaken, the minimum test matrix shown in *Table 1.3.1 Minimum test matrix* is required to be carried out:

Table 1.3.1 Minimum test matrix

Item	Test matrix
Sea state	Regular and irregular seas
Heading	Beam, head, stern and quartering seas
Speed	Three speeds including zero and maximum service speeds
Wave frequency	Six frequencies

3.2.2 In addition to those quantities which are normally measured in a model experiment, the following data are to be obtained where practicable:

(a) Vertical accelerations at the LCG, bow and stern.
(b) Acceleration loads due to heave and pitch.
(c) Vertical bending moment.
(d) Bow impact pressures at full forward speed.
(e) Oblique sea loads inducing dynamic torque on the cross structure for multi-hull craft.
(f) Splitting loads due to beam seas and roll motion for multi-hull craft.
(g) Impact pressures in tunnel side and top for multi-hull craft.

3.2.3 The basis on which the parameters are chosen for investigation is to be submitted for approval.

3.2.4 Results from open water model experiments and full scale measurements may be accepted and full details are to be submitted for appraisal.

■ *Section 1* Environmental conditions

1.1 General

1.1.1 This Chapter contains information regarding the derivation of load criteria which are to be used for the computation of local design criteria in *Pt 5, Ch 3 Local Design Criteria for Craft Operating in Non-Displacement Mode* and *Pt 5, Ch 4 Local Design Criteria for Craft Operating in Displacement Mode*.

1.1.2 Environmental conditions include natural phenomena such as wind, wave and currents from which design data are to be derived.

1.1.3 These environmental conditions are usually described by physical variables of statistical nature.

1.1.4 The load criteria used for design are to be based on environmental data for the specific area and operation of the craft.

1.1.5 The loads imposed by the environment are to be based on extreme conditions. These arise as the craft advances in a seaway and is loaded and stressed in a random manner by dynamic forces and moments.

1.1.6 The load criteria given here are derived from experimental and theoretical studies complemented with service experience.

1.1.7 Alternative methods of establishing the load criteria will be specially considered, provided that they are based on model tests, full scale measurements or generally accepted theories. In such cases, full details of the methods used are to be provided when plans are submitted for approval.

■ *Section 2* Definitions and symbols

2.1 Parameters to be used for the determination of load and design criteria

2.1.1 **Air gap.** The air gap, G_A, is the minimum vertical distance, in metres, from the static waterline to the point considered in an operational condition. In no case is G_A to be taken greater then $G_{A(max)}$ as indicated in *Figure 2.2.1 Definition of air gap*.

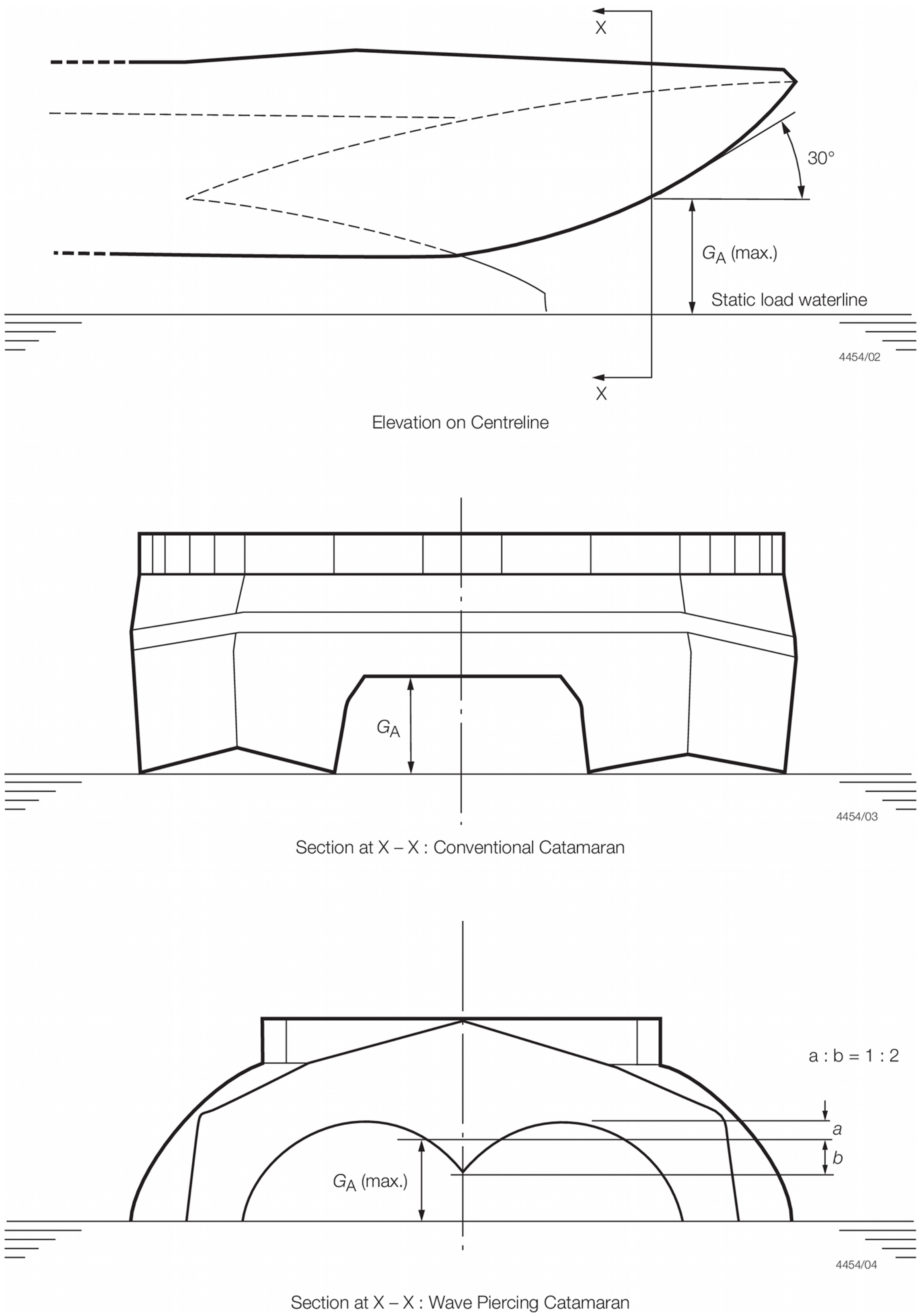


Figure 2.2.1 Definition of air gap

2.1.2 **Allowable speed *V*.** The allowable speed used in the computation of environmental loads is the design speed, in knots, associated with a nominated operational environment in which the craft is certified at corresponding operational displacement.

2.1.3 **Beaufort Number.** Beaufort Number is a measure of wind strength.

2.1.4 **Bilge tangential point.** For craft with partially submerged hull(s), the bilge tangential point is defined as the tangential point of the bilge with an oblique line sloped at 50° to the horizontal at the LCG, *see Figure 2.2.2 Definition of bilge tangential point and G_s for craft with partially submerged hulls* . For craft with fully submerged hull(s), the bilge tangential point is defined as the intersection points between the hull and the design waterline.

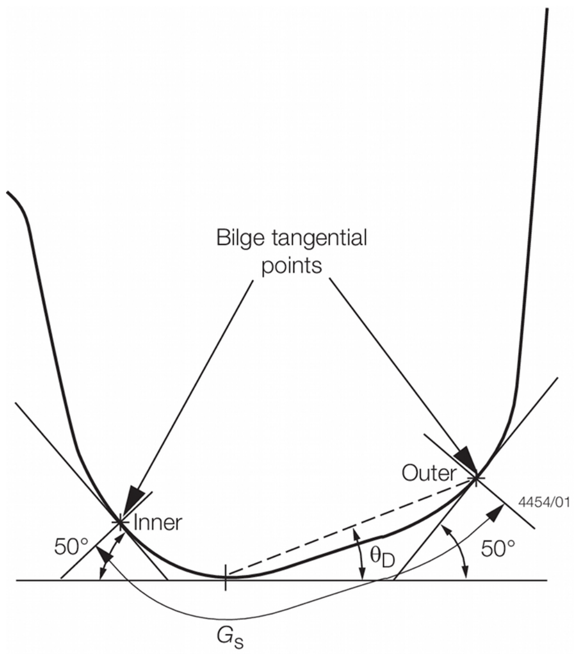


Figure 2.2.2 Definition of bilge tangential point and *G* s for craft with partially submerged hulls

2.1.5 **Deadrise angle.** For craft with no clearly defined deadrise angle at the LCG, the angle, in degrees, to the horizontal of the line at the LCG formed by joining the lowest point of the hull or underside of keel and the bilge tangential point is to be taken as the deadrise angle θ_D, *see Figure 2.2.2 Definition of bilge tangential point and G_s for craft with partially submerged hulls* . For craft with hulls of asymmetric section, where the inner and outer deadrise angles differ, the smaller of the two angles is to be used. For craft with fully submerged hull with circular sections, the deadrise angle is to be taken as 30°.

2.1.6 **Displacement mode.** Displacement mode means the regime, whether at rest or in motion, where the weight of the craft is fully or predominantly supported by hydrostatic forces.

2.1.7 **Froude Number F_n.** The Froude Number is a non-dimensional speed parameter and is defined as:

$$F_n = \frac{0,515 V_m}{\sqrt{g L_{WL}}}$$

where

= g is the acceleration due to gravity and is taken to be 9,81 m/s^2.

= L_{WL} is defined in *Pt 5, Ch 2, 2.1 Parameters to be used for the determination of load and design criteria 2.1.19*.

= V_m is the appropriate speed in knots.

2.1.8 **LCG.** The LCG is the longitudinal centre of gravity of the craft in the loading condition under consideration.

2.1.9 **Maximum wave height.** In general the maximum wave height, in metres, will be taken as 1,667 times the significant wave height. Where, for design purposes, a wave length is required this will be taken as the waterline length subject to any restriction resulting from limiting height to length ratio and wave profile angle.

2.1.10 **Non-displacement mode.** Non-displacement mode means the normal operational regime of a craft when non-hydrostatic forces substantially or predominantly support the weight of the craft.

2.1.11 **Operating waterline** is the waterline for the operating condition under consideration.

2.1.12 **Period.** The period is defined as the average time interval between upward crossings of the mean value.

2.1.13 **Sea state.** Sea state is an expression used to categorise wave conditions and is normally defined by sea spectrum, significant wave height and period distribution.

2.1.14 **Significant wave height $H_{1/3}$.** The wave height, in metres, used in the determination of craft motions and loads is a significant wave height, $H_{1/3}$, defined as the average of the one third highest waves in a short term wave measurement record.

2.1.15 **Support girth.** The support girth, G_s, is the girth distance, in metres, measured around the circumference of the shell plate between the tangential points or chines, as appropriate, of the hull for a mono-hull craft. For multi-hull craft it is to be taken between the inner and outer bilge tangential points or chines of the individual hulls. *See Pt 5, Ch 2, 2.1 Parameters to be used for the determination of load and design criteria 2.1.4* and *Figure 2.2.2 Definition of bilge tangential point and G_s for craft with partially submerged hulls* .

2.1.16 **Surviving wave height H_{03}.** The wave height, in metres, used in the determination of the structural integrity of a craft and is defined as the wave height with three per cent probability of exceedance. If this value is unknown, the following equation is to be used to determine H_{03}:

$$H_{03} = 1,29 H_{1/3}$$

2.1.17 **Taylor Quotient** Γ . The Taylor Quotient is defined as

$$\Gamma = \frac{V}{\sqrt{L_{\mathrm{WL}}}}$$

where V is defined in *Pt 5, Ch 2, 2.1 Parameters to be used for the determination of load and design criteria 2.1.2* and L_{WL} is defined in *Pt 5, Ch 2, 2.1 Parameters to be used for the determination of load and design criteria 2.1.19*.

2.1.18 **Volumetric speed number F_v.** The Volumetric speed number is defined as:

$$F_v = 7,19 \nabla^{1/6}$$

where ∇ is the moulded displacement, in m^3, of the craft corresponding to the design waterline.

2.1.19 **Waterline length.** Waterline length (L_{WL}) is as defined in *Pt 3, Ch 1, 6.2 Principal particulars*

2.1.20 **Protected structure**, *see Figure 2.2.3 Definition of wet-deck protected and unprotected structure*. A protected structure is one in which the wet-deck component under consideration is enclosed by port and starboard side inboard structure, where `side inboard' is as defined in Ch 4,1.5.6 of Parts *Pt 6, Ch 4, 1.5 Symbols and definitions 1.5.6*, *Pt 7, Ch 4, 1.5 Symbols and definitions 1.5.6* and *Pt 8, Ch 4, 1.5 Symbols and definitions 1.5.6* for craft of steel, aluminium alloy and composite construction respectively.

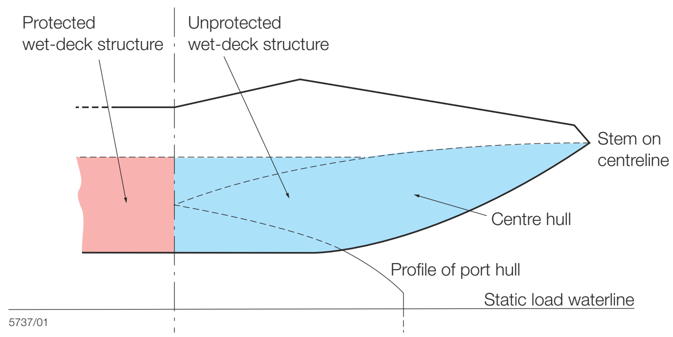


Figure 2.2.3 Definition of wet-deck protected and unprotected structure

2.1.21 **Unprotected structure**, *see Figure 2.2.3 Definition of wet-deck protected and unprotected structure*. An unprotected structure is one in which the wet-deck component under consideration is not enclosed by port and starboard side inboard structure, where `side inboard' is as defined in Ch 4,1.5.6 of Parts *Pt 6, Ch 4, 1.5 Symbols and definitions 1.5.6*, *Pt 7, Ch 4, 1.5 Symbols and definitions 1.5.6* and *Pt 8, Ch 4, 1.5 Symbols and definitions 1.5.6* for craft of steel, aluminium alloy and composite construction respectively.

2.2 Symbols

2.2.1 L_R, B, D, C_b, L_{WL} and T are as defined in *Pt 3, Ch 1, 6.2 Principal particulars*.

x_{wl} = longitudinal distance, in metres, measured forwards from the aft end of the L_{WL} to the position or centre of gravity of the item being considered

z = vertical distance, in metres, from the baseline to the position of centre of gravity of the item being considered. z is positive above the baseline

= Normally the following definitions are to be applied:

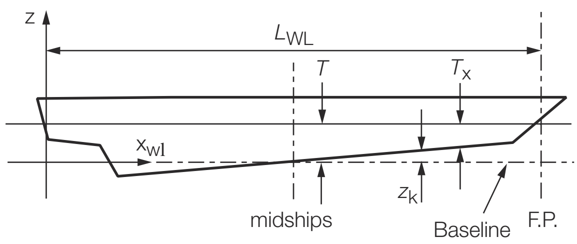
= z is to be taken at one third of the panel or strake height

= For short stiffener members: z is to be taken at the stiffener mid position

= For long stiffener members: z is generally to be taken at the stiffener mid position, but may need to be specially considered, especially when there is a significant pressure variation along its length

z_k = vertical distance of the underside of the keel above the baseline, in metres, *see Figure 2.2.1 Definition of air gap*

T_x = local draught measured from the underside of the keel to the operating waterline at the longitudinal position under consideration *see Figure 2.2.1 Definition of air gap*



NOTE
For any Position $T = z_k + T_x$

Figure 2.2.4 Definition of Symbols

2.2.2 The displacement, Δ, in tonnes, used in this Part is the mass of the craft in the loading condition under consideration.

2.3 Minimum significant wave height

2.3.1 The minimum value of significant wave height, $H_{1/3}$, *see Pt 5, Ch 2, 2.1 Parameters to be used for the determination of load and design criteria 2.1.14*, in metres, used in the determination of accelerations and loads is, in general, not to be taken less than that given in *Table 2.2.1 Minimum significant wave height, $H_{1/3}$* for the appropriate Service Groups defined in *Pt 1, Ch 2, 3.5 Service area restriction notations*.

2.3.2 The designer/Builder is to provide the value of significant wave height for use in the determination of the Rule loadings and, further, is to ensure that such a wave height is appropriate to the intended area of operation and/or service. In this respect the statistical wave data may be required to be submitted in support of the wave height nominated.

2.3.3 A reduction in the minimum value of significant wave height for a particular Service Group will be specially considered, provided that satisfactory statistical wave data for the intended service area are submitted for approval. *See also Pt 5, Ch 2, 2.1 Parameters to be used for the determination of load and design criteria 2.1.14*.

Table 2.2.1 Minimum significant wave height, $H_{1/3}$

Service Group	Minimum significant wave height, in metres
1	0,6
2	1,0
2A	1,5
3	2,0
4	4,0
5	4,0
6	4,0

■ Section 3
Motion response

3.1 Relative vertical motion

3.1.1 The relative vertical motion is to be taken as:

$$H_{rm} = C_{w,min}\left(1 + \frac{k_r}{(C_b + 0,2)}\left(\frac{x_{wl}}{L_{WL}} - x_m\right)^2\right)$$

where

k_r = *see Table 2.3.1 Hull form wave pressure factor*

$C_{w,min}$ = $\frac{C_w}{k_m}$

k_m = $1 + \frac{k_r(0,5 - x_m)^2}{(C_b + 0,2)}$

x_m = 0,45 – 0,6F_n but not less than 0,2

C_w = wave head, in metres

= $0,0771 L_{WL}\,(C_b + 0,2)^{0,3}\,e^{(-0,0044 L_{WL})}$

x_{wl} = distance from aft end of L_{WL}, in metres, *see Pt 5, Ch 2, 2.2 Symbols 2.2.1*

L_{WL} = waterline length, in metres, *see Pt 5, Ch 2, 2.1 Parameters to be used for the determination of load and design criteria 2.1.19*

C_b = block coefficient, *see Pt 5, Ch 2, 2.2 Symbols*

F_n = Froude Number, *see Pt 5, Ch 2, 2.1 Parameters to be used for the determination of load and design criteria 2.1.7*, where V_m = 2/3V

V = as defined in *Pt 5, Ch 2, 2.1 Parameters to be used for the determination of load and design criteria 2.1.2*.

Table 2.3.1 Hull form wave pressure factor

Craft type	k_r
Mono-hull craft in the non-displacement mode	2,25
Mono-hull craft in the displacement mode	1,95
Catamarans and multi-hull craft with partially submerged hulls	2,55
Swaths and multi-hull craft with fully submerged hulls	2,10
Craft supported by hydrodynamic lift provided by foils or other lifting devices	1,50
Note Where multiple craft types apply, the higher value of k_r is to be used.	

3.2 Vertical acceleration

3.2.1 The instantaneous accelerations determined in accordance with the formulae in this Section are to be used to estimate the relationship between allowable speed, V, in knots, wave height, $H_{1/3}$, in metres, and displacement, Δ, in tonnes, and they will form the operational envelope.

3.2.2 Where the Taylor Quotient, Γ, is greater than 10,8, the motion response criteria are to be specially considered.

3.2.3 The vertical acceleration at the LCG (longitudinal centre of gravity), a_v, is defined as the average of the 1/100 highest accelerations at the LCG.

3.2.4 The vertical acceleration in the non-displacement mode for mono-hull craft is to be taken as:

$$a_v = 1,5\,\theta_B L_l (H_l + 0,084)(5 - 0,1\,\theta_D)\,\Gamma^2 \times 10^{-3}$$

where

= a_v is the vertical acceleration at the LCG in terms of g

Γ = Taylor Quotient, *see Pt 5, Ch 2, 2.1 Parameters to be used for the determination of load and design criteria 2.1.17*

g = acceleration due to gravity (9,81 m/sec^2)

L_1 = $\dfrac{L_{WL}B^3_c}{B_W \Delta}$, but $\dfrac{L_{WL}}{B_W}$ is not to be taken as less than 3

H_1 = $\dfrac{H_{1/3}}{B_W}$, but is not to be taken as less than 0,2

B_c = breadth of hull between the chines or bilge tangential points at LCG, as appropriate, in metres

B_W = breadth of hull at the LCG measured at the waterline, in metres

Δ = displacement, in tonnes, as defined in *Pt 5, Ch 2, 2.2 Symbols 2.2.2*

$H_{1/3}$ = design significant wave height in metres

θ_D = deadrise angle at the LCG, in degrees, but is not to be taken as greater than 30°

θ_B = running trim angle in degrees, but is not to be taken as less than 3°

L_{WL} = waterline length, in metres, *see Pt 5, Ch 2, 2.1 Parameters to be used for the determination of load and design criteria 2.1.19*

3.2.5 The vertical acceleration in the non-displacement mode for multi-hull craft is to be taken as:

$$a_v = \frac{f_a L_{WL}}{\Delta}\left(B_M H_{1/3} + 0,084B^2_M\right)\left(5 - 0,1\,\theta_D\right)\Gamma^2 \times 10^{-3}$$

where

= a_v is the vertical acceleration at the LCG in terms of g.

Γ = Taylor Quotient, *see Pt 5, Ch 2, 2.1 Parameters to be used for the determination of load and design criteria 2.1.17*

f_a = hull form acceleration factor

= 2,7 for craft supported mainly by hydrodynamic lift provided by foils or other lifting devices

= 3,6 for Swaths and multi-hull craft with fully submerged hulls

= 4,5 for catamarans and multi-hull craft with partially submerged hulls

B_M = total breadth of hulls or struts at LCG at the waterline, in metres, excluding tunnels

Δ = displacement, in tonnes.

$H_{1/3}$ = design significant wave height, in metres

θ_D = deadrise angle at the LCG, in degrees, but is not to be taken as greater than 30°, *see Pt 5, Ch 2, 2.1 Parameters to be used for the determination of load and design criteria 2.1.5*

L_{WL} = waterline length, in metres, *see Pt 5, Ch 2, 2.1 Parameters to be used for the determination of load and design criteria 2.1.19*

3.2.6 The vertical acceleration in the displacement mode for all craft is to be taken as:

$$a_v = 0,2\,\Gamma + \frac{34}{L_{WL}}$$

where

= a_v is the vertical acceleration at the LCG in terms of g

where

L_{WL} = waterline length, in metres, *see Pt 5, Ch 2, 2.1 Parameters to be used for the determination of load and design criteria 2.1.19*

Γ = Taylor's Quotient, *see Pt 5, Ch 2, 2.1 Parameters to be used for the determination of load and design criteria 2.1.17*

3.2.7 The vertical acceleration, a_x, at any given location distance x_a from the AP along the hull may be taken as:

$$a_x = a_v\left(0,86 - 0,32\frac{x_a}{L_{WL}} + 1,76\left(\frac{x_a}{L_{WL}}\right)^2 + \xi_a\right)$$

where

a_v = vertical acceleration at LCG in terms of g, as appropriate.

a_x = is the vertical acceleration at distance x_a from AP on the static load waterline, in terms of g

x_a = distance from aft end of the static load waterline, in metres, to the point at which the vertical acceleration is calculated

x_{LCG} = distance from aft end of the static load waterline, in metres, to the LCG

L_{WL} = waterline length, in metres, *see Pt 5, Ch 2, 2.1 Parameters to be used for the determination of load and design criteria 2.1.19*

ξ_a = $0,14 + 0,32\frac{x_{LCG}}{L_{WL}} - 1,76\left(\frac{x_{LCG}}{L_{WL}}\right)^2$.

■ *Section 4*
Loads on shell envelope

4.1 Pressures on the shell envelope

4.1.1 The design pressures for the shell envelope including exposed decks are to include the effects of combined static and dynamic load components. In addition, the effects of impact or slamming loads are also to be considered, but these are to be treated separately, *see Pt 5, Ch 2, 5 Impact loads*.

4.1.2 The individual pressure components are given in *Pt 5, Ch 2, 4.3 Hydrostatic pressure on the shell plating* and the combined pressure to be applied to the shell envelope is given in *Pt 5, Ch 2, 4.2 Combined hydrostatic and hydrodynamic pressure on the shell plating*. The pressure to be applied to exposed and weather decks is given in *Pt 5, Ch 2, 4.5 Pressure on weather and interior decks*.

4.2 Combined hydrostatic and hydrodynamic pressure on the shell plating

4.2.1 The total pressure distribution, P_s, in kN/m^2 acting on the shell plating envelope due to hydrostatic and hydrodynamic pressures is illustrated in *Figure 2.4.1 Combined pressure distribution, P_s* and is to be taken as specified in *Table 2.4.1 Combined pressure distribution, P_s* .

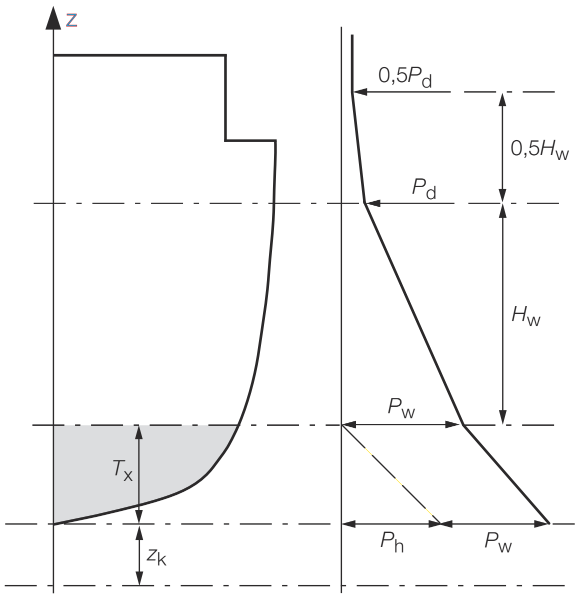


Figure 2.4.1 Combined pressure distribution, P_s

Table 2.4.1 Combined pressure distribution, P_s

Vertical location i.e. z value	Shell envelope pressure, P_s kN/m^2
for $z \le T_x + z_k$ i.e. up to the operating waterline	$P_h + P_w$
At $z = T_x + z_k + H_w$	P_d
At $z \ge T_x + z_k + 1{,}5H_w$	$0{,}5P_d$
Symbols	
H_w is the nominal wave limit height, *see Pt 5, Ch 2, 4.4 Hydrodynamic wave pressure 4.4.4* P_d is the weather deck pressure, *see Pt 5, Ch 2, 4.5 Pressure on weather and interior decks 4.5.1* P_h is the hydrostatic pressure, *see Pt 5, Ch 2, 4.3 Hydrostatic pressure on the shell plating* P_w is the hydrodynamic wave pressure, *see Pt 5, Ch 2, 4.4 Hydrodynamic wave pressure* P_h and P_w are to be derived at the appropriate vertical position, z T_x, z and z_k are defined in *Pt 5, Ch 2, 2.2 Symbols*	
Note Pressure values at other z values are to be derived by interpolation.	

4.3 Hydrostatic pressure on the shell plating

4.3.1 The pressure, P_h, acting on the shell plating up to the operating waterline due to hydrostatic pressure is to be taken as:

$$P_h = 10\left(T_x - \left(z - z_k\right)\right) \text{ kN/m}^2$$

where

T_x, z and z_k are defined in *Pt 5, Ch 2, 2.2 Symbols*.

4.4 Hydrodynamic wave pressure

4.4.1 The hydrodynamic wave pressure distribution due to relative motion, P_w, around the shell envelope up to the operating waterline, i.e. $z \leq T$ is to be taken as the greater of the following:

$$P_m \text{ kN/m}^2$$

as defined in *Pt 5, Ch 2, 4.4 Hydrodynamic wave pressure 4.4.2*

$$P_p \text{ kN/m}^2$$

as defined in *Pt 5, Ch 2, 4.4 Hydrodynamic wave pressure 4.4.3*.

4.4.2 The distribution of hydrodynamic pressure up to the operating waterline, P_m, is to be taken as:

$$P_m = 10 f_z H_{rm} \text{ kN/m}^2$$

where

f_z = the vertical distribution factor

= $k_z + (1 - k_z)\left(\frac{z - z_k}{T_x}\right)$

k_z = e^{-u}

u = $\left(\frac{2\pi\ T_x}{L_{WL}}\right)$

H_{rm} is defined in *Pt 5, Ch 2, 3.1 Relative vertical motion 3.1.1*

z, z_k, T_x and L_{WL} are defined in *Pt 5, Ch 2, 2.2 Symbols*.

4.4.3 The distribution of hydrodynamic pressure up to the operating waterline P_p, is to be taken as:

$$P_p = 10 H_{pm} \text{ kN/m}^2$$

where

H_{pm} = $1,1\left(\frac{2x_{wI}}{L_{WL}} - 1\right)\sqrt{L_{WL}}$

= but not less than $f_L\sqrt{L_{WL}}$

where

f_L = 0,6 for $L_{WL} < 60$

= 1,5 - 0,015L_{WL} for $60 \leq L_{WL} \leq 80$

= 0,3 for $L_{WL} > 80$

L_{WL} = as defined in *Pt 5, Ch 2, 2.1 Parameters to be used for the determination of load and design criteria 2.1.19*, but not greater than 150m x_{wl} is defined in *Pt 5, Ch 2, 3.1 Relative vertical motion*.

x_{wl} and L_{WL} are defined in *Pt 5, Ch 2, 3.1 Relative vertical motion*.

4.4.4 The nominal wave limit height, H_w, above the design draft, T_x, is to be taken as:

$$H_w = 2H_{rm} \text{ m}$$

where

H_{rm} is given in *Pt 5, Ch 2, 3.1 Relative vertical motion 3.1.1*.

4.5 Pressure on weather and interior decks

4.5.1 The pressure acting on weather decks, P_d, is to be taken as specified in *Pt 5, Ch 2, 4.5 Pressure on weather and interior decks 4.5.2* or *Pt 5, Ch 2, 4.5 Pressure on weather and interior decks 4.5.3* as applicable.

4.5.2 The pressure acting on weather and interior decks, P_{wh}, in the displacement mode is to be taken as:

$$P_{wh} = f_L(6 + 0,01L_{WL})(1 + 0,05\,\Gamma) + E \text{ kN/m}^2$$

where

f_L = the location factor for weather decks

= 1,0 from aft end to 0,88L_R

= 1,25 from 0,88L_R to 0,925L_R

= 1,50 from 0,925L_R to forward end

f_L = 1,0 for interior decks

E = $\dfrac{0,7 + 0,08L_{WL}}{D - T}$ kN/m^2 for exposed decks but need not be taken greater than 3 kN/m^2

E = 0,0 for interior decks and superstructure decks aft of the forward quarter

Γ = Taylor Quotient as defined in *Pt 5, Ch 2, 2.1 Parameters to be used for the determination of load and design criteria 2.1.17*, and

Δ = the displacement as defined in *Pt 5, Ch 2, 2.2 Symbols*

L_{WL} is as defined in *Pt 5, Ch 2, 2.1 Parameters to be used for the determination of load and design criteria 2.1.19*.

4.5.3 The pressure acting on weather and interior decks, P_{wl}, in the non-displacement mode is to be taken as:

$$P_{wl} = f_L(5 + 0,01L_{WL})(1 + 0,5a_v) + E \text{ kN/m}^2$$

where f_L and E are as defined in *Pt 5, Ch 2, 4.5 Pressure on weather and interior decks 4.5.2*, and a_v is as defined in *Pt 5, Ch 2, 3 Motion response*.

- a_v is not to be taken less than 1,0, but need not be taken greater than 4,0 for weather decks.
- a_v need not be taken greater than 1,0 for interior decks.

L_{WL} is as defined in *Pt 5, Ch 2, 2.1 Parameters to be used for the determination of load and design criteria 2.1.19*.

■ *Section 5* Impact loads

5.1 Impact pressure for displacement mode

5.1.1 The impact pressure, P_{dh}, for mono-hull and multi-hull craft is to be taken as specified in *Pt 5, Ch 2, 5.1 Impact pressure for displacement mode 5.1.2* and *Pt 5, Ch 2, 5.1 Impact pressure for displacement mode 5.1.3* as applicable.

5.1.2 The bottom shell impact pressure due to bottom slamming, is given by the following expression:

$$P_{dh} = \Phi_{dh}\left(19 - 2720\left(\frac{T_x}{L_{WL}}\right)^2\right)\sqrt{L_{WL}V} \text{ kN/m}^2$$

$P_{dh} \geq P_m$

Φ_{dh} = 0,09 at L_{WL} from aft end of L_{WL}

= 0,18 at 0,9L_{WL} from aft end of L_{WL}

= 0,18 at 0,8L_{WL} from aft end of L_{WL}

= 0,0 between aft end of L_{WL} and 0,5L_{WL} from aft end of L_{WL}

L_{WL} = waterline length, in metres, *see Pt 5, Ch 2, 2.1 Parameters to be used for the determination of load and design criteria 2.1.19*

V = allowable speed, in knots, *see Pt 5, Ch 2, 2.1 Parameters to be used for the determination of load and design criteria 2.1.2*.

Intermediate values to be determined by linear interpolation. T_x is taken to be the draught T, as defined in *Pt 3, Ch 1, 6 Definitions*, but need not be taken greater than 0,08L_{WL}.

P_{dh} at 0,9L_{WL} and 0,8L_{WL} from aft end of L_{WL} need not be taken greater than P_f at L_{WL} from aft end of L_{WL} as defined in *Pt 5, Ch 2, 5.4 Forebody impact pressure for displacement mode 5.4.1*.

5.1.3 The side shell impact pressure shall be taken as P_{dh} at the operating waterline, reducing to 0,4P_{dh} at the weather deck. Intermediate values between the weather deck at side and operating waterline, are to be determined by linear interpolation.

5.2 Impact pressure for non-displacement mode

5.2.1 The impact pressure, P_{dl}, for mono-hull and multi-hull craft is to be taken as specified in *Pt 5, Ch 2, 5.2 Impact pressure for non-displacement mode 5.2.2* and *Pt 5, Ch 2, 5.2 Impact pressure for non-displacement mode 5.2.3* as applicable.

5.2.2 The bottom impact pressure due to slamming, P_{dlb} is given by the following expression:

$$P_{\text{dlb}} = \frac{f_{\text{d}} \Delta \ \Phi \left(1 + a_v\right)}{L_{\text{WL}} G_{\text{o}}} \ \text{kN/m}^2$$

where

G_o = support girth or girth distance, in metres, as defined in *Table 2.5.1 Definition of G_o for the determination of bottom impact pressure, P_{dl} for different regions of the hull*

L_{WL} = waterline length, in metres, *see Pt 5, Ch 2, 2.1 Parameters to be used for the determination of load and design criteria 2.1.19*

a_v = vertical acceleration as defined in *Pt 5, Ch 2, 3.1 Relative vertical motion*

Δ = displacement, in tonnes, *see Pt 5, Ch 2, 2.2 Symbols 2.2.2*

f_d = hull form pressure factor

= 54 for mono-hull craft

= $\frac{81}{N_H}$ for catamarans and multi-hull craft, where

= N_H is the number of hulls, but it is not to be taken as greater than four

= For craft in continuous contact with water:

Φ = 0,5 at L_{WL} from aft end of L_{WL}

= 1,0 at 0,75L_{WL} from aft end of L_{WL}

= 1,0 at 0,5L_{WL} from aft end of L_{WL}

= 0,5 at aft end of L_{WL}

Intermediate values to be determined by linear interpolation.

Otherwise, Φ = 1,0

5.2.3 The side shell impact pressure due to slamming is to be taken as:

$$P_{\text{dls}} = P_{\text{dlb}} \frac{\text{Tan}\left(40 - \theta_{\text{B}}\right)}{\text{Tan}\left(\theta_{\text{S}} - 40\right)} \ \text{kN/m}^2$$

but is not to be taken as greater than P_{dlb}

where

θ_B = mean deadrise angle of bottom plating, in degrees at local section,

θ_S = mean deadrise angle of side plating, in degrees at local section,

(40 – θ_B) is not to be taken as less than 10°

(θ_S – 40) is not to be taken as less than 10°

P_{dls} is to be taken as constant from the chine or operating waterline to a point half G_o from the chine, or the weather deck if this is reached first. Multiple chines will be subject to special consideration based on the above principle. *See Figure 2.5.1 Angles used in determination of side shell pressure for planing craft, P_{dls}* .

Table 2.5.1 Definition of G_o for the determination of bottom impact pressure, P_{dl} for different regions of the hull

Bottom shell region	G_o	
	Craft with chines	Craft without chines
Between tangential points or chines	G_S	G_S
Between tangential points and design waterline	-	G_{WL}
Note 1. G_S = support girth, in metres, as defined in *Pt 5, Ch 2, 2.1 Parameters to be used for the determination of load and design criteria 2.1.15* at LCG.		
Note 2. G_{WL} = girth distance, in metres, measured between the waterlines on either side of a hull at the LCG.		

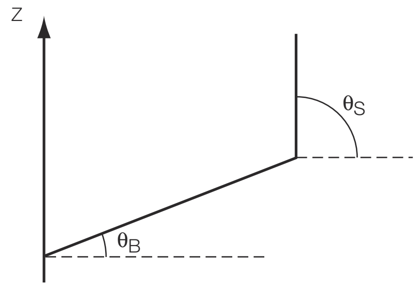


Figure 2.5.1 Angles used in determination of side shell pressure for planing craft, P_{dls}

5.3 Impact pressure for craft with foils and lifting devices

5.3.1 The impact pressure, P_{fb}, for craft supported by hydrodynamic lift provided by foils or other lifting devices is to be taken as specified in *Pt 5, Ch 2, 5.3 Impact pressure for craft with foils and lifting devices 5.3.2* and *Pt 5, Ch 2, 5.3 Impact pressure for craft with foils and lifting devices 5.3.3* as applicable.

5.3.2 The bottom impact pressure, is given by the greater of P_{fba} or P_{fbb}, where:

$$P_{fba} = \frac{16}{L_{WL}}\left(H_{03} + \sqrt{H_0 L_{WL}}\right)^2 \text{ kN/m}^2$$

$$P_{fbb} = \frac{1}{3} K_{po} V_R V \left(1 - \frac{H_0}{H_{03}}\right) \text{ kN/m}^2$$

where

K_{po} = longitudinal distribution factor

= 1,0 between the aft end of the L_{WL} and 0,75L_{WL}

= 2,0 at L_{WL} from the aft end of L_{WL}, intermediate values to be determined by linear interpolation

H_0 = operational height of craft, in metres, measured from the waterline to the top of the keel at LCG

H_{03} = surviving waveheight as defined in *Pt 5, Ch 2, 2.1 Parameters to be used for the determination of load and design criteria 2.1.15* but is not taken as less than 1,0

L_{WL} = waterline length, in metres, *see Pt 5, Ch 2, 2.1 Parameters to be used for the determination of load and design criteria 2.1.19*

V = allowable speed in knots, *see Pt 5, Ch 2, 2.1 Parameters to be used for the determination of load and design criteria 2.1.2*

P_{fbb} is not taken as less than zero.

V_R is the relative vertical speed of the craft at impact, in knots. If this value is unknown, then the following equation is to be used:

$$V_R = \frac{8H_{1/3}}{\sqrt{L_{WL}}} + 2 \text{ knots}$$

5.3.3 The side shell impact pressure shall be taken as P_{fb} at the chine or at the operating waterline for round bilge hullforms as appropriate reducing to 0,3P_{fb} at the weather deck. Intermediate values between the weather deck at side and the chine or operating waterline, as appropriate, to be determined by linear interpolation.

5.4 Forebody impact pressure for displacement mode

5.4.1 Forebody and bow slamming pressure, P_f, at the load waterline due to relative motion is to be taken as:

P_f = $f_f L_{WL} (0,8 + 0,15\Gamma)^2$ kN/m^2 at FP

= P_{dh} at 0,9L_{WL} from aft end of L_{WL}

= P_m at 0,75L_{WL} from aft end of L_{WL}

= 0,0 between aft end of L_{WL} and 0,75L_{WL} from aft end of L_{WL}

Intermediate values to be determined by linear interpolation.

where

f_f = forebody impact pressure factor as defined in *Table 2.5.2 Forebody impact pressure factor*

L_{WL} = waterline length, in metres, *see Pt 5, Ch 2, 2.1 Parameters to be used for the determination of load and design criteria 2.1.19*

Γ = Taylor Quotient, *see Pt 5, Ch 2, 2.1 Parameters to be used for the determination of load and design criteria 2.1.17*.

Table 2.5.2 Forebody impact pressure factor

Craft type	f_f
Mono-hull craft in non-displacement mode	0,94
Mono-hull craft in displacement mode	0,89
Catamarans and multi-hull craft with partially submerged hulls	1,0
Swaths and multi-hull craft with fully submerged hulls	0,91

Craft supported by hydrodynamic lift provided by foils or other lifting devices	0,81
Note Where multiple craft types apply, the higher value of f_f is to be used.	

5.4.2 The side shell impact pressure shall be taken as P_f at the chine or at the operating waterline for round bilge hullforms as appropriate reducing to $0,4P_f$ at the weather deck. Intermediate values between the weather deck at side and the chine or operating waterline, as appropriate, are to be determined by linear interpolation.

5.5 Forebody impact pressure for non-displacement mode

5.5.1 Forebody and bow slamming pressure, P_f, at the load waterline due to relative motion is to be taken as:

P_f = the greater of $P_{d/s}$ or $f_f L_{WL}$ $(0,8 + 0,15\Gamma)2$ kN/m^2 at FP

= $P_{d/s}$ at $0,75L_{WL}$ from aft end of L_{WL}

= P_m at < $0,5L_{WL}$ from aft end of L_{WL}

= 0,0 between aft end of L_{WL} and $0,5L_{WL}$ from aft end of L_{WL}

Intermediate values to be determined by linear interpolation.

where

f_f = forebody impact pressure factor as defined in *Table 2.5.2 Forebody impact pressure factor*

L_{WL} = waterline length, in metres, *see Pt 5, Ch 2, 2.1 Parameters to be used for the determination of load and design criteria 2.1.19*

Γ = Taylor Quotient, *see Pt 5, Ch 2, 2.1 Parameters to be used for the determination of load and design criteria 2.1.17*.

5.5.2 The side shell impact pressure shall be taken as P_f at the chine or at the operating waterline for round bilge hullforms as appropriate reducing to $0,3P_f$ at the weather deck. Intermediate values between the weather deck at side and the chine or operating waterline, as appropriate, are to be determined by linear interpretation.

■ *Section 6*
Cross-deck structure for multi-hull craft

6.1 Cross-deck structure clearance

6.1.1 For craft with multi-hulls linked by cross-deck structure, sufficient clearance is to be provided between the cross-deck structure and water surface to limit impact loads.

6.1.2 Where part or all of the cross-deck is intended to provide additional buoyancy to limit craft motion, the loading will be specially considered.

6.1.3 In the determination of the clearance, the following factors are to be considered:

(a) Relative motion in waves.
(b) The wave generated between the hulls when running.
(c) The bow sinkage.

6.1.4 The submitted clearance must be validated either by calculations according to accepted theories, model tests, full scale measurements or by documentary evidence if similar structures have proved to be satisfactory in service.

6.1.5 Where it is not possible to provide sufficient clearance to avoid slamming of the cross-deck structure, the equation given in *Pt 5, Ch 2, 6.2 Impact pressure* is to be used for the assessment of the impact pressures.

6.2 Impact pressure

6.2.1 The impact pressure, P_{pc}, acting on the underside of the cross deck (`wet deck') is to be taken as:

$$P_{pc} = \nabla_{pc} K_{pc} V_R V \left(1 - \frac{G_A}{H_{03}}\right) \text{kN/m}^2$$

where

K_{pc} = longitudinal distribution factor

= 1,0 between the aft end of the L_{WL} and 0,75L_{WL}

= 2,0 at the L_{WL} from the aft end of L_{WL}, intermediate values to be determined by linear interpolation

∇_{pc} = cross-deck Impact Factor

= 1/6 for protected structures, as defined in *Pt 5, Ch 2, 2.1 Parameters to be used for the determination of load and design criteria 2.1.20*

= 1/3 for unprotected structures, as defined in *Pt 5, Ch 2, 2.1 Parameters to be used for the determination of load and design criteria 2.1.21*

G_A = air gap, as defined in *Pt 5, Ch 2, 2.1 Parameters to be used for the determination of load and design criteria 2.1.1*

H_{03} = surviving waveheight, as defined in *Pt 5, Ch 2, 2.1 Parameters to be used for the determination of load and design criteria 2.1.16*

V = allowable speed, as defined in *Pt 5, Ch 2, 2.1 Parameters to be used for the determination of load and design criteria 2.1.2*

V_R is the relative vertical speed of the craft at impact, in knots. If this value is unknown, then the following equation is to be used:

$$V_R = \frac{8H_{1/3}}{\sqrt{L_{WL}}} + 2 \ knots$$

6.2.2 The impact pressure, P_{pc}, should not be taken less than zero.

■ Section 7
Component design loads

7.1 Deckhouses, bulwarks and superstructures

7.1.1 The component design pressure, P_{dhp}, for the plating of deckhouses, bulwarks and first tier and above superstructures is given by:

$$P_{dhp} = C_1 \, P_d \ \ \text{kN/m}^2$$

G_f and S_f are defined in *Pt 5, Ch 3 Local Design Criteria for Craft Operating in Non-Displacement Mode* or *Pt 5, Ch 4 Local Design Criteria for Craft Operating in Displacement Mode* as appropriate.

P_d is defined in *Pt 5, Ch 2, 4.5 Pressure on weather and interior decks*.

For structures other than windows:

C_1 = 1,25 for deckhouse and superstructure fronts on upper deck within the forward third of L_R

= 1,15 for deckhouse and superstructure fronts on upper deck outside the forward third of L_R and exposed machinery casings on the upper deck

= 1,0 for deckhouse and superstructure fronts above the lowest tier

= 0,8 for superstructure sides. A value of 0,64 may be used where the sides of the superstructure are stepped in from the sides of the craft by 1,0 m or more

= 0,5 elsewhere

L_R = Rule length in metres, *see Pt 5, Ch 2, 2.2 Symbols 2.2.1*

For windows of toughened safety glass the component design pressure, P_{dhp}, is to be calculated taking C_1 as follows:

$$C_1 = W_1 W_2 W_3$$

For windows positioned on the first tier, C_1 is not to be taken less than that used for the deckhouse plating P_d for windows may be tapered to 0,5P_d in accordance with *Table 2.4.1 Combined pressure distribution, P_s* .

where

W_1 = 2,0 for the lowest tier of unprotected front

= 1,5 for superstructure fronts above the lowest tier

= 1,0 for superstructure sides. A value of 0,8 may be used where the sides of the superstructure are stepped in from the sides of the craft by 1,0 metre or more

= 0,67 elsewhere

W_2 = 0,67 + 0,33 (x_b/L_{WL}) where $x_b > 0{,}5L_{WL}$ from AP

= 0,67 elsewhere

W_3 = 1 – (y – F)/y

x_b = distance, in metres, from AP

y = vertical distance, in metres, from the static load waterline at the deepest design draught to the structural element considered

F = (D – T) in metres

G_f and S_f are defined in *Pt 5, Ch 3 Local Design Criteria for Craft Operating in Non-Displacement Mode* or *Pt 5, Ch 4 Local Design Criteria for Craft Operating in Displacement Mode* as appropriate. P_d is defined in *Pt 5, Ch 2, 4.5 Pressure on weather and interior decks*.

L_{WL}, D and T are as defined in *Pt 3, Ch 1, 6.2 Principal particulars*.

7.2 Watertight and deep tank bulkheads

7.2.1 The design pressure, P_{bh}, on watertight and deep tank bulkheads is to be taken as:

P_{bh} = 11,2 h_b kN/m^2 for:

- deep tank bulkheads,
- watertight bulkhead doors and
- stiffening supporting watertight bulkheads in way of watertight doors

where

h_b = load head in metres, measured as described in (b)

= 7,2 h_b kN/m^2 for:

- watertight bulkhead plating and
- stiffening clear of watertight doors

where

h_b = load head in metres, measured as described below in (a) for deep tank bulkheads and (c) for doors

(a) Watertight bulkheads:

(i) Plating: the distance from a point one-third of the height of the plate above its lower edge to the bulkhead deck at side.
(ii) Stiffeners: the distance from the mid-point of the stiffener span to the bulkhead deck at side.

(b) Deep tank bulkheads:

For determination of head, the overflow is to be taken as not less than 1,8 m above the crown of the tank.

(i) Plating: the greater of:

- the distance from the point one-third of the height of the plate above its lower edge to the top of the tank
- half the distance from a point one third of the height of the plate above its lower edge to the top of the overflow.

(ii) Stiffeners: the greater of:

- the distance from the mid-point of the span to the top of the tank
- half the distance from mid-point of span to the top of the overflow.

(c) Watertight door and supporting construction

(i) Plating: the distance from the point one-third of the height of the plate above its lower edge to the main deck
(ii) Stiffeners: the distance from the mid-point of the span the main deck

7.3 Pillars

7.3.1 The design load, P_{Pl}, supported by a pillar is to be taken as:

$$P_{\mathrm{PI}} = S_{\mathrm{gt}}\, b_{\mathrm{gt}}\, P_{\mathrm{c}} + P_{\mathrm{a}} \ \ \mathrm{kN}$$

where

P_c = basic deck girder design pressure, as appropriate, plus any other loadings directly above the pillar, in kN/m^2

P_a = load, in kN, from pillar or pillars above, assumed zero if there are no pillars over

S_{gt} = spacing, or mean spacing, of girders or transverses, in metres

b_{gt} = distance between centres of two adjacent spans of girders or transverses supported by the pillar, in metres

P_{Pl} is not to be taken less than 5 kN.

7.4 Deck area designed for cargo, stores and equipment

7.4.1 The cargo deck design pressure, P_{cd}, for plating is to be taken as:

$$P_{\mathrm{cd}} = W_{\mathrm{CDP}}\left(1 + 0,5a_{\mathrm{x}}\right) \ \ \mathrm{kN/m^2}$$

where a_x is given in *Pt 5, Ch 2, 3.2 Vertical acceleration 3.2.7* and is not to be taken as less than 1,0.

W_{CDP} is the pressure exerted by the cargo on deck specified by the designer in kN/m^2.

Local Design Criteria for Craft Operating in Non-Displacement Mode

■ *Section 1* General

1.1 Application

1.1.1 The design criteria given in this Chapter are applicable to craft when operating in the non-displacement mode, *see Pt 5, Ch 1, 1.1 General*.

1.1.2 Planing and semi-planing craft are craft with Taylor's Quotient, Γ, as defined in *Pt 5, Ch 2, 2.1 Parameters to be used for the determination of load and design criteria 2.1.17*, greater than or equal to 3,0.

1.1.3 Light displacement craft are craft with displacement, Δ, in tonnes, less than or equal to $0{,}04(L_R B)^{1{,}5}$, as defined in *Pt 1, Ch 2, 2.2 Definitions 2.2.11*.

1.1.4 The design criteria detailed in this Chapter are to be used in conjunction with the load criteria given in *Pt 5, Ch 2 Local Design Loads* together with the strength formulae given in *Pt 6 Hull Construction in Steel*, *Pt 7 Hull Construction in Aluminium* and *Pt 8 Hull Construction in Composite* to determine the scantlings of steel, aluminium alloy and composite craft respectively as defined in *Pt 1 Regulations*.

1.1.5 Alternative methods of establishing the design criteria will be specially considered, provided that they are based on established Codes or Standards acceptable to LR. In such cases, full details of the methods used are to be provided when plans are submitted for approval.

■ *Section 2* Nomenclature and design factors

2.1 Nomenclature

2.1.1 The nomenclature used in this Chapter is given below:

P_p = pitching pressure, *see Pt 5, Ch 2, 4.4 Hydrodynamic wave pressure*

P_{dl} = impact pressure *see Pt 5, Ch 2, 5.2 Impact pressure for non-displacement mode*

P_{fb} = impact pressure for craft supported by hydrodynamic lift provided by foils or other lifting devices, *see Pt 5, Ch 2, 5.3 Impact pressure for craft with foils and lifting devices*

P_s = shell envelope pressure, *see Pt 5, Ch 2, 4.2 Combined hydrostatic and hydrodynamic pressure on the shell plating*

P_f = forebody impact pressure, *see Pt 5, Ch 2, 5.5 Forebody impact pressure for non-displacement mode*

P_{cd} = cargo tank pressure, *see Pt 5, Ch 2, 7.4 Deck area designed for cargo, stores and equipment*

P_{dhp} = deckhouse, bulwalks and superstructure pressure, *see Pt 5, Ch 2, 7.1 Deckhouses, bulwarks and superstructures*

P_{bh} = watertight and deep tank bulkhead pressure, *see Pt 5, Ch 2, 7.2 Watertight and deep tank bulkheads*

P_{pc} = impact pressure acting on the cross-deck structure, *see Pt 5, Ch 2, 6.2 Impact pressure*

P_{wl} = pressure on weather deck, *see Pt 5, Ch 2, 4.5 Pressure on weather and interior decks*

P_{BP} = design pressure for bottom plating

P_{BF} = design pressure for bottom stiffening

P_{SP} = design pressure for side shell plating

P_{SF} = design pressure for side shell stiffening

P_{CP} = design pressure for cross-deck plating

P_{CF} = design pressure for cross-deck stiffening

P_{h} = hydrostatic pressure, *see Pt 5, Ch 2, 4.3 Hydrostatic pressure on the shell plating*

P_{WDP} = design pressure for weather deck plating

P_{WDF} = design pressure for weather deck stiffening

P_{CRP} = design pressure for coachroof plating

P_{CRF} = design pressure for coachroof stiffening

P_{IDP} = design pressure for interior deck plating

P_{IDF} = design pressure for interior deck stiffening

P_{IBP} = design pressure for inner bottom plating

P_{IBF} = design pressure for inner bottom stiffening

P_{DHP} = design pressure for deckhouse, bulwarks and superstructures plating and windows

P_{DHF} = design pressure for deckhouse, bulwarks and superstructure stiffening

P_{BHP} = design pressure for bulkheads

P_{CDP} = design pressure for cargo deck plating

Δ and Γ are defined in *Pt 5, Ch 2, 2.2 Symbols 2.2.2* and *Pt 5, Ch 2, 2.1 Parameters to be used for the determination of load and design criteria 2.1.17*

T, L_R and B are as defined in *Pt 3, Ch 1, 6.2 Principal particulars*.

2.1.2 The unit for pressure is kN/m^2.

2.1.3 The design pressure, P, used in the scantling formulae given in *Pt 3 General Requirements and Constructional Arrangements*, *Pt 6 Hull Construction in Steel*, *Pt 7 Hull Construction in Aluminium* and *Pt 8 Hull Construction in Composite* is to be taken as equal to the appropriate value as defined in this Chapter.

2.2 Design factors

2.2.1 The design pressures on structural components are to be calculated taking into consideration the following factors:

(a) Hull notation assigned as defined in *Pt 1, Ch 2, 3.4 High speed craft and light displacement craft notations*.
(b) Service area restriction notation assigned as defined in *Pt 1, Ch 2, 3.5 Service area restriction notations*.

(c) Service type notation assigned as defined in *Pt 1, Ch 2, 3.6 Service type notations*.
(d) Craft type notation assigned as defined in *Pt 1, Ch 2, 3.7 Craft type notations*.
(e) Type of stiffening members.

2.2.2 In general, the design pressure, in kN/m^2, for a particular structural component is to be determined as follows:

Design pressure = $\delta_f H_f G_f S_f C_f$ x load criterion

where

H_f = hull notation factor given in *Table 3.2.1 Hull notation factor, H_f*

G_f = service area restriction notation factor given in *Table 3.2.2 Service area notation factor, G_f*

S_f = service type factor notation given in *Table 3.2.3 Service type notation factor, S_f*

C_f = craft type notation factor given in *Table 3.2.4 Craft type notation factor, C_f*

δ_f = stiffening type factor as given in *Table 3.2.5 Stiffening type factor, δ_f*

Table 3.2.1 Hull notation factor, H_f

Hull notation	Factor
HSC	1,0
LDC	0,95

Note For a craft eligible for both **HSC** and **LDC** notation, the higher value is to be used. H_f is to be taken as 1,0 for a craft not eligible for either the **HSC** or the **LDC** notation.

Table 3.2.2 Service area notation factor, G_f

Service area restriction notation	Factor
G1, Zone 3	0,6
G2, Zone 2	0,75
G2A, Zone 1	0,8
G3	0,85
G4	1,0
G5	1,2
G6	1,25

Table 3.2.3 Service type notation factor, S_f

Service type notation	Factor
Cargo (A)	1,0
Cargo (B)	1,1
Passenger	1,0
Passenger (A)	1,0
Passenger (B)	1,1
Patrol	1,2

Pilot	1,25
Yacht	1,1
Workboat	1,25

Table 3.2.4 Craft type notation factor, C_f

Craft type notation	Factor
Catamaran	1,0
Hydrofoil	1,1
Mono	1,0
Multi	1,1
RIB	1,15
SES	1,0
SWATH	1,0

Table 3.2.5 Stiffening type factor, δ_f

Type	δ_f
Primary stiffening members and transverse frames	0,5
Secondary and local stiffening members Transverse beams	0,8

■ *Section 3*
Hull envelope design criteria

3.1 Hull structures

3.1.1 The design pressures, in kN/m^2, to be used to determine the scantlings of structural elements are to be taken as specified in *Table 3.3.1 Design pressures for non-displacement craft*.

Table 3.3.1 Design pressures for non-displacement craft

Category/location	Craft type	Symbol	Plating pressure	Min.	Symbol	Stiffener pressure	Min.
Mono-hull craft							

Bottom shell	Basic craft	P_{BP}	Greater of $H_f S_f P_s$ $H_f S_f C_f P_{dl}$ $H_f S_f G_f C_f P_f$		P_{BF}	Greater of $\delta_f H_f S_f P_s$ $\delta_f H_f S_f C_f P_{dl}$ $\delta_f H_f S_f G_f C_f P_f$	
	Craft with foils or other lifting devices	P_{BP}	Greater of $H_f S_f P_s$ $H_f S_f C f P_{fb}$		P_{BF}	Greater of $\delta_f H_f S_f P_s$ $\delta_f H_f S_f C_f P_{fb}$	
Side Shell		P_{SP}	P_{BP}		P_{SF}	$\delta_f P_{BP}$	
Multi-hull craft							
Bottom shell	Basic craft	P_{BP}	Greater of $H_f S_f P_s$ $H_f S_f C_f P_{dl}$ $H_f S_f G_f C_f P_f$		P_{BF}	Greater of $\delta_f H_f S_f P_s$ $\delta_f H_f S_f C_f P_{dl}$ $\delta_i H_f S_f G_f C_f P_f$	
	Craft with foils or other lifting devices	P_{BP}	Greater of $H_f S_f P_s$ $H_f S_f C f P_{fb}$		P_{BF}	Greater of $\delta_f H_f S_f P_s$ $\delta_f H_f S_f C_f P_{fb}$	
	Fully submerged hulls	P_{BP}	Greater of $H_f S_f P_s$ $H_f S_f G_f P_f$		P_{BF}	Greater of $\delta_f H_f S_f P_s$ $\delta_f H_f S_f G_f P_f$	
Outboard side shell		P_{SP}	P_{BP}		P_{SF}	$\delta_f P_{BP}$	
Inboard side shell		P_{SP}	Greater of P_{BP} 1,6 P_{WDP} at wet deck		P_{SF}	Greater of $\delta_f P_{BP}$ 1,9 P_{WDP} at wet deck	
Wet deck		P_{CP}	Greater of $H_f S_f P_s$ $H_f S_f P_{pc}$		P_{CF}	Greater of $\delta_f H_f S_f P_s$ $\delta_f H_f S_f P_{pc}$	
Components							
Weather deck *see* Note 1		P_{WDP}	Greater of $H_f S_f G_f C_f P_{wl}$ P_{cd}	7	P_{WDF}	Greater of $\delta_f H_f S_f G_f C_f P_{wl}$ P_{cd}	7
Coachroof deck, *see* Note 1		P_{CRP}	$H_f S_f G_f C_f P_{wl}$	7	P_{CRF}	$\delta_f H_f S_f G_f C_f P_{wl}$	7
Interior deck		P_{IDP}	Greater of $H_f S_f C_f P_{wl}$ P_{cd}	3,5	P_{IDF}	Greater of $\delta_f H_f S_f C_f P_{wl}$ P_{cd}	3,5
Deckhouses, bulwarks and superstructure		P_{DHP}	$H_f S_f G_f C_f P_{dhp}$		P_{DHF}	$\delta_f H_f S_f G_f C_f P_{dhp}$	

Deckhouse windows of toughened safety glass		P_{DHP}	H_f S_f G_f C_f P_{dhp} For windows on first tier and deckhouse fronts All other windows	 7 5			
Inner bottom		P_{IBP}	$H_f S_f P_m + P_h$	$10T$	P_{IBF}	$\delta_f (H_f S_f P_m + P_h)$	$10T$
Watertight and deep tank bulkheads		P_{BHP}	P_{bh}		P_{BHF}	P_{bh}	

Note 1. G_f is not to be taken less than 1,0.

Note 2. The result of each row in each cell is found as the product of all items on that row in that cell.

■ *Section 1* General

1.1 Application

1.1.1 The design criteria given in this Chapter are applicable to all craft when operating in the displacement mode, *see Pt 5, Ch 4, 1.1 Application*.

1.1.2 Displacement craft are craft with Taylor's Quotient, Γ, as defined in *Pt 5, Ch 2, 2.1 Parameters to be used for the determination of load and design criteria 2.1.17*, less than 3,0 and with displacement, Δ, in tonnes, greater than 0,04(L_R B)1,5, as defined in *Pt 5, Ch 2, 2.2 Symbols 2.2.2*.

1.1.3 The design criteria detailed in this Chapter are to be used in conjunction with the load criteria given in *Pt 5, Ch 2 Local Design Loads* together with the strength formulae given in *Pt 6 Hull Construction in Steel*, *Pt 7 Hull Construction in Aluminium* and *Pt 8 Hull Construction in Composite* to determine the scantlings of steel, aluminium alloy and composite craft as defined in *Pt 1 Regulations*.

1.1.4 Alternative methods of establishing the design criteria will be specially considered, provided that they are based on established Codes or Standards acceptable to LR. In such cases, full details of the methods used are to be provided when plans are submitted for approval.

■ *Section 2* Nomenclature and design factors

2.1 Nomenclature

2.1.1 The nomenclature used in this Chapter is given below:

P_p = pitching pressure, *see Pt 5, Ch 2, 4.4 Hydrodynamic wave pressure*

P_{dh} = impact pressure, *see Pt 5, Ch 2, 5.1 Impact pressure for displacement mode*

P_{dhp} = deckhouse, bulkwarks and superstructure pressure, *see Pt 5, Ch 2, 7.1 Deckhouses, bulwarks and superstructures*

P_s = shell envelope pressure, *see Pt 5, Ch 2, 4.1 Pressures on the shell envelope*

P_f = forebody impact pressure, *see Pt 5, Ch 2, 5.4 Forebody impact pressure for displacement mode*

P_{pc} = impact pressure acting on the cross-deck structure, *see Pt 5, Ch 2, 6.2 Impact pressure*

P_{wh} = pressure on weather deck, *see Pt 5, Ch 2, 4.5 Pressure on weather and interior decks*

P_{cd} = cargo, *see Pt 5, Ch 2, 7.4 Deck area designed for cargo, stores and equipment*

P_{bh} = watertight and deep tank bulkhead pressure, *see Pt 5, Ch 2, 7.2 Watertight and deep tank bulkheads*

P_{BP} = design pressure for bottom plating

P_{BF} = design pressure for bottom stiffening

P_{SP} = design pressure for side shell plating

P_{SF} = design pressure for side shell stiffening

P_{CP} = design pressure for cross-deck plating

P_{CF} = design pressure for cross-deck stiffening

P_{h} = hydrostatic pressure, *see Pt 5, Ch 2, 4.3 Hydrostatic pressure on the shell plating*

P_{WDP} = design pressure for weather deck plating

P_{WCDF} = design pressure for weather deck stiffening

P_{CRP} = design pressure for coachroof plating

P_{CRF} = design pressure for coachroof stiffening

P_{IDP} = design pressure for interior deck plating

P_{IDF} = design pressure for interior deck stiffening

P_{IBP} = design pressure for inner bottom plating

P_{IBF} = design pressure for inner bottom stiffening

P_{DHP} = design pressure for deckhouse, bulwarks and superstructures plating and windows

P_{DHF} = design pressure for deckhouse, bulwarks and superstructure stiffening

P_{BHP} = design pressure for bulkheads

P_{CDP} = design pressure for cargo deck plating

Δ and Γ are defined in *Pt 5, Ch 2, 2.2 Symbols 2.2.2* and *Pt 5, Ch 2, 2.1 Parameters to be used for the determination of load and design criteria 2.1.17*.

T, L_R and B are as defined in *Pt 3, Ch 1, 6.2 Principal particulars*.

2.1.2 The unit for pressure is kN/m^2.

2.1.3 The design pressure, P, used in the scantling formulae given in *Pt 3 General Requirements and Constructional Arrangements*, *Pt 6 Hull Construction in Steel*, *Pt 7 Hull Construction in Aluminium* and *Pt 8 Hull Construction in Composite* is to be taken as equal to the appropriate value as defined in this Chapter.

2.2 Design factors

2.2.1 The design pressures on structural components are to be calculated taking into consideration the following factors:

(a) Hull notation assigned as defined in *Pt 1, Ch 2, 3.4 High speed craft and light displacement craft notations*.
(b) Service area restriction notation assigned as defined in *Pt 1, Ch 2, 3.5 Service area restriction notations*.
(c) Service type notation assigned as defined in *Pt 1, Ch 2, 3.6 Service type notations*.
(d) Type of stiffening members.

2.2.2 In general, the design pressure, in kN/m^2, for a particular structural component is to be determined as follows:

Design pressure = $\delta_f H_f G_f S_f$ x load criterion

where

H_f = 1,05

G_f = service area restriction notation factor given in *Table 4.2.1 Service area restriction notation factor, G_f*

S_f = service type factor notation given in *Table 4.2.2 Service type notation factor, S_f*

δ_f = stiffening type factor as given in *Table 4.2.3 Stiffening type factor, δ_f*

Table 4.2.1 Service area restriction notation factor, G_f

Service area restriction notation	Factor
G1, Zone 3	0,6
G2, Zone 2	0,75
G2A, Zone 1	0,8
G3	0,85
G4	1,0
G5	1,2
G6	1,25

Table 4.2.2 Service type notation factor, S_f

Service type notation	Factor
Cargo (A)	1,0
Cargo (B)	1,1
Passenger	1,0
Passenger (A)	1,0
Passenger (B)	1,1
Patrol	1,2
Pilot	1,25
Yacht	1,1
Workboat	1,25

Table 4.2.3 Stiffening type factor, δ_f

Type	δ_f
Primary stiffening members and transverse frames	0,5
Secondary and local stiffening members Transverse beams	0,8

Section 3
Hull envelope design criteria

3.1 Hull structures

3.1.1 The design pressures, in kN/m^2, to be used to determine the scantlings of structural elements are to be taken as specified in *Table 4.3.1 Design pressures for displacement craft*.

Table 4.3.1 Design pressures for displacement craft

Category/location	Craft type	Symbol	Plating pressure	Min.	Symbol	Stiffener pressure	Min.
Mono-hull craft							
Bottom shell	Basic craft	P_{BP}	Greater of $H_f S_f P_s$ $H_f S_f G_f P_{dh}$ $H_f S_f G_f P_f$		P_{BF}	Greater of $\delta_f H_f S_f P_s$ $\delta_f H_f S_f G_f P_{dh}$ $\delta_f H_f S_f G_f P_f$	
Side shell		P_{SP}	P_{BP}		P_{SF}	$\delta_f P_{BP}$	
Mono-hull craft							
Bottom shell	Partially submerged hulls	P_{BP}	Greater of $H_f S_f P_s$ $H_f S_f G_f P_{dh}$ $H_f S_f G_f P_f$		P_{BF}	Greater of $\delta_f H_f S_f P_s$ $\delta_f H_f S_f G_f P_{dh}$ $\delta_f H_f S_f G_f P_f$	
	Fully submerged hulls	P_{BP}	Greater of $H_f S_f P_s$ $H_f S_f G f P_f$		P_{BF}	Greater of $\delta_f H_f S_f P_s$ $\delta_f H_f S_f G_f P_f$	
Outboard side shell		P_{SP}	P_{BP}		P_{SF}	$\delta_f P_{BP}$	
Inboard side shell		P_{SP}	Greater of P_{BP} 1,6 P_{WDP} at wet deck		P_{SF}	Greater of $\delta_f P_{BP}$ 1,9 P_{WDP} at wet deck	
Wet deck		P_{CP}	Greater of $H_f S_f P_s$ $H_f S_f P_{pc}$		P_{CF}	Greater of $\delta_f H_f S_f P_s$ $\delta_f H_f S_f P_{pc}$	
Components							
Weather deck, *see* Note 1		P_{WDP}	Greater of $H_f S_f G_f P_{wh}$ P_{cd}	7	P_{WDF}	Greater of $\delta_f H_f S_f G_f P_{wh}$ P_{cd}	7
Coachroof, *see* Note 1		P_{CRP}	$H_f S_f G_f P_{wl}$	7	P_{CRF}	$\delta_f H_f S_f G_f P_{w1}$ (see Note1)	7

Interior deck		P_{IDP}	Greater of $H_f S_f P_{wh}$ P_{cd}	3,5	P_{IDF}	Greater of $\delta_f H_f S_f P_{wh}$ P_{cd}	3,5
Deckhouses, bulwarks and superstructure		P_{DHP}	$H_f S_f G_f P_{dhp}$		P_{DHF}	$\delta_f H_f S_f G_f P_{dhp}$	
Deckhouse windows of toughened safety glass		P_{DHP}	$H_f S_f G_f P_{dhp}$ For windows on first tier and deckhouse fronts All other windows	7 5			
Inner bottom		P_{IBP}	$H_f S_f P_m + P_h$	$10T$	P_{IBF}	$\delta_f (H_f S_f P_s + P_h)$	$10T$
Watertight and deep tank bulkheads		P_{BHP}	P_{bh}		P_{BHF}	P_{bh}	

Note 1. G_f is not to be taken less than 1,0.

Note 2. The result of each row in each cell is found as the product of all items on that row in that cell.

■ *Section 1* General

1.1 Introduction

1.1.1 The global load and design criteria detailed in this Chapter are to be used in conjunction with *Pt 6 Hull Construction in Steel*, *Pt 7 Hull Construction in Aluminium* and *Pt 8 Hull Construction in Composite* to determine the global hull strength requirements for steel, aluminium alloys and composite craft respectively as defined in *Pt 1, Ch 2, 2.1 Applicable craft types 2.1.1*.

1.1.2 The global load and design criteria given in this Chapter are also provided to enable the designer/Builder to check global hull strength against ductile failure modes involving gross deformation.

1.1.3 The global load criteria are divided into two categories:

(a) Hull girder loads

The types of hull girder loads which are to be considered for strength purposes are distinguished on the basis of their frequencies and they are defined as follows:

(i) Still water bending moments and associated shear forces arising from mass distribution and buoyancy forces.
(ii) Vertical wave bending moments and associated shear forces arising from low frequency hydrodynamic forces.
(iii) Dynamic bending moments and associated shear forces arising from high frequency bottom slamming.

(b) Primary loads for multi-hull craft

These loads arise from the interaction between the hulls and waves.

1.1.4 Alternative methods of establishing the global load and design criteria will be specially considered, provided that they are based on model tests, full scale measurements or other generally accepted theories. In such cases, full details of the methods used and the results are to be provided when plans are submitted for approval.

1.1.5 Longitudinal strength calculations are to be carried out and submitted for approval for craft as required in *Pt 6 Hull Construction in Steel*, *Pt 7 Hull Construction in Aluminium* and *Pt 8 Hull Construction in Composite*, as appropriate, covering the range of load and ballast conditions proposed, in order to determine the required hull girder strength. The calculations of still water shear forces and bending moments are to cover both departure and arrival conditions and any special mid-voyage conditions caused by changes in ballast distribution.

1.1.6 L_R, B, D T and C_b are as defined in *Pt 3, Ch 1, 6 Definitions*.

1.1.7 The vertical acceleration at the LCG, a_v, in terms of g, as defined in *Pt 5, Ch 2, 3.2 Vertical acceleration*, as appropriate, is not to be taken less than 1,0 for the purpose of determining the global load and design criteria.

Section 2
Hull girder load criteria for mono-hull craft

2.1 General

2.1.1 The vertical bending moments specified here are applicable to all mono-hull craft as defined in *Pt 1, Ch 2, 2.2 Definitions 2.2.14*.

2.2 Vertical wave bending moments

2.2.1 For all craft except patrol craft in Service Group G6, the minimum value of vertical wave bending moment, M_W at any position along the craft is to be taken as follows:

$$M_W = F_f D_f M_o \text{ kN m}$$

where

F_f = –1,1 for sagging (negative) moment

= $1,9C_b/(C_b + 0,7)$ for hogging (positive) moment

D_f = the longitudinal distribution factor

= 0 at aft end of L_R

= 1,0 between $0,4L_R$ and $0,65L_R$

= 0 at forward end of L_R

Intermediate values of D_f are to be determined by linear interpolation

M_o = $0,1L_f G_f L_R{}^2 B (C_b + 0,7)$ kN m

L_f = $0,0412L_R + 4,0$, for $L_R < 90$ m

= $10,75 - (3 - 0,01L_R)^{1,5}$ for $L_R \geq 90$ m

G_f = Service group factor, *see Pt 1, Ch 2, 3.5 Service area restriction notations 3.5.5*

= 0,5 for G1 craft and Zone 3 craft

= 0,6 for G2 craft and Zone 2 craft

= 0,65 for G2A craft and Zone 1 craft

= 0,7 for G3 craft

= 0,8 for G4 craft

= 1,0 for G5 and G6 craft (yachts only)

L_R = Rule length, in metres, as defined in *Pt 3, Ch 1, 6 Definitions*

= C_b to be taken not less than 0,60.

2.2.2 For patrol craft in Service Group G6, the minimum value of vertical wave bending moment, M_W, at any position along the ship may be taken as follows:

$$M_W = F_f D_f M_o \text{ kN m}$$

where

F_f is the hogging, F_{fH}, or sagging, F_{fS}, correction factor based on the amount of bow flare, stern flare, length and effective buoyancy of the aft end of the craft above the waterline. F_{fS} is the sagging (negative) moment correction factor and is to be taken as:

F_{fS} = $-1{,}10R_A^{\ 0,3}$ for values of $R_A \geq 1{,}0$

F_{fS} = $-1{,}10$ for values of $R_A < 1{,}0$

R_A is an area ratio factor, *see Pt 5, Ch 5, 2.2 Vertical wave bending moments 2.2.3*

An area ratio value of 1,0 results in a sagging correction factor of –1,10

F_{fH} is the hogging (positive) moment correction factor and is to be taken as

F_{fH} = $1{,}9C_b/(C_b + 0{,}7)$

D_f = the longitudinal distribution factor

= 0 at aft end of L_R

= 1,0 between $0{,}4L_R$ and $0{,}65L_R$

= 0 at forward end of L_R

Intermediate values of D_f are to be determined by linear interpolation

M_o = $0{,}1L_f\,L_R^{\ 2}B_{WL}\,(C_b + 0{,}7)$ kNm

L_f = $0{,}0412L_R + 4{,}0$, for $L_R < 90$ m

= $10{,}75 - (3 - 0{,}01L_R)^{1,5}$ for $L_R \geq 90$ m

B_{WL} = maximum breadth at the design waterline, in metres

= C_b to be taken not less than 0,60.

2.2.3 The area ratio factor, R_A, for the combined stern and bow shape is to be derived as follows:

$$R_A = \frac{30\left(A_{BF} + 0,5A_{SF}\right)}{L_R B_{WL}}$$

where

A_{BF} is the bow flare area, in m^2, *see Pt 5, Ch 5, 2.2 Vertical wave bending moments 2.2.4*

A_{SF} is the stern flare area, in m^2, *see Pt 5, Ch 5, 2.2 Vertical wave bending moments 2.2.5*.

2.2.4 The bow flare area, A_{BF}, is illustrated in *Figure 5.2.1 Derivation of bow and stern flare areas* and may be derived as follows:

$$A_{BF} = A_{UB} - A_{LB} \ \ \mathrm{m}^2$$

where

A_{UB} = half the water plane area at a waterline of $T_{C,U}$ of the bow region of the hull forward of $0{,}8L_R$ from the A_P.

A_{LB} = half the water plane area at the design waterline of the bow region of the hull forward of $0{,}8L_R$ from the AP.

Note the AP is to be taken at the aft end of the Rule length, L_R. The design waterline is to be taken at T, *see Pt 3, Ch 1 General Regulations*. Alternatively the following formula may be used:

$$A_{BF} = 0,05L_R\left(b_o + 2b_1 + b_2\right) + b_0\,\mathrm{a}/2 \ \ \mathrm{m}^2$$

where

b_0 = projection of $T_{C,U}$ waterline outboard of the design waterline at the FP, in metres, *see Figure 5.2.1 Derivation of bow and stern flare areas*

b_1 = projection of $T_{C,U}$ waterline outboard of the design waterline at $0{,}9L_R$ from the AP, in metres

b_2 = projection of $T_{C,U}$ waterline outboard of the design waterline at $0{,}8L_R$ from the AP, in metres

where

a = projection of $T_{C,U}$ waterline forward of the FP, in metres

$T_{C,U}$ is a waterline taken L_f /2 m above the design waterline

$$T_{C,U} = T + L_f/2 \text{ m}$$

L_f is given in *Pt 5, Ch 5, 2.2 Vertical wave bending moments 2.2.2*.

For ships with large bow flare angles above the $T_{C,U}$ waterline the bow flare area may need to be specially considered.

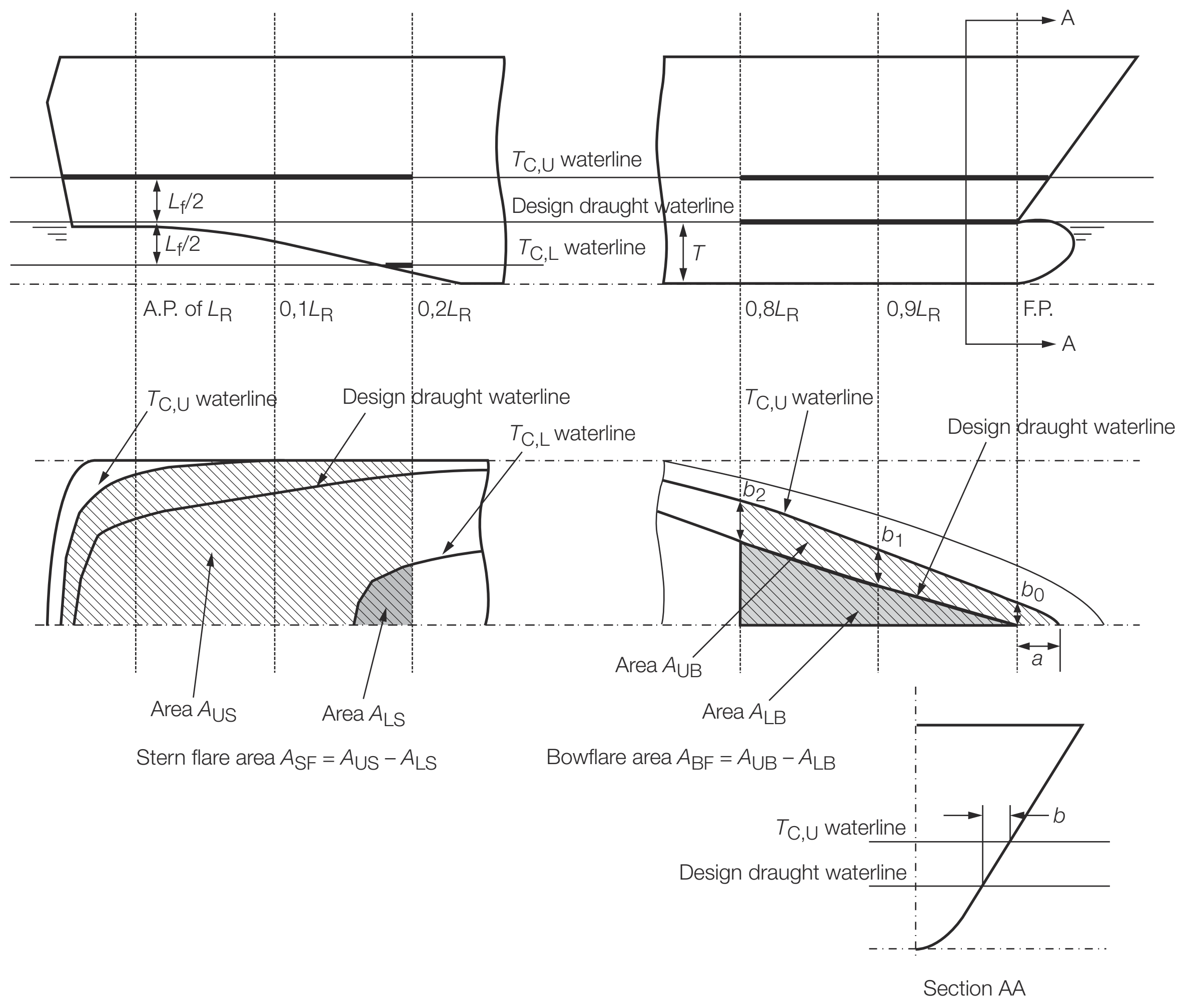


Figure 5.2.1 Derivation of bow and stern flare areas

2.2.5 The stern flare area, A_{SF}, is illustrated in *Figure 5.2.1 Derivation of bow and stern flare areas* and is to be derived as follows:

$$A_{SF} = A_{US} - A_{LS} \text{ m}^2$$

where

A_{US} = half the water plane area at a waterline of $T_{C,U}$ of the stern region of the hull from aft to 0,2L_R forward of the AP

where

A_{LS} = half the water plane area at a waterline of $T_{C,L}$ of the stern region of the hull from aft to $0{,}2L_R$ forward of the AP

$T_{C,L}$ is a waterline taken $L_f/2$ m below the design waterline

$$T_{C,L} = T - L_f/2 \text{ m}$$

L_f is given in *Pt 5, Ch 5, 2.2 Vertical wave bending moments 2.2.2*.

For craft with tumblehome in the stern region, the maximum breadth at any waterline less than $T_{C,U}$ is to be used in the calculation of A_{US}. The effects of appendages including bossings are to be ignored in the calculation of A_{LS}.

2.2.6 The sagging correction factor, F_{fS} , in the vertical wave bending moment formulation in *Pt 5, Ch 5, 2.2 Vertical wave bending moments 2.2.2* may be derived by direct calculation methods. Appropriate direct calculation methods may include a combination of long term ship motion analysis, non linear ship motion analysis and static balance on a wave crest or trough.

2.3 Still water bending moments

2.3.1 The still water bending moment, M_S, hogging and sagging is the maximum moment calculated from the loading conditions.

2.3.2 Still water bending moments are to be calculated along the craft length. For these calculations, downward loads are to be taken as positive values and are to be integrated in the forward direction from the aft end of L_R. Hogging bending moments are positive.

2.4 Wave shear force

2.4.1 The wave shear force, Q_W, at any position along the craft is given by:

$$Q_W = \frac{3K_f M_O}{L_R} \text{ kN}$$

where K_f is to be taken as follows:

(a) Positive shear force:

K_f = 0 at aft end of L_R

= $1{,}589C_b/(C_b + 0{,}7)$ between $0{,}2L_R$ and $0{,}3L_R$ from aft end of L_R

= 0,7 between $0{,}4L_R$ and $0{,}6L_R$ from aft end of L_R

= 1,0 between $0{,}7L_R$ and $0{,}85L_R$ from aft end of L_R

= 0 at forward end of L_R

(b) Negative shear force:

K_f = 0 at aft end of L_R

= - 0,92 between $0{,}2L_R$ and $0{,}3L_R$ from aft end of L_R

= - 0,7 between $0{,}4L_R$ and $0{,}6L_R$ from aft end of L_R

= $- 1{,}727C_b/(C_b + 0{,}7)$ between $0{,}7L_R$ and $0{,}85L_R$ from aft end of L_R

= 0 at forward end of L_R

Intermediate values to be determined by linear interpolation.

M_o, C_b are as defined in *Pt 5, Ch 5, 2.2 Vertical wave bending moments 2.2.1* and *Pt 5, Ch 5, 2.2 Vertical wave bending moments 2.2.2*.

2.5 Still water shear force

2.5.1 The still water shear force, Q_s, at each transverse section along the hull is to be taken as the maximum positive and negative value found from the longitudinal strength calculations.

2.5.2 Still water shear forces are to be calculated at each section along the craft length. For these calculations, downward loads are to be taken as positive values and are to be integrated in a forward direction from the aft end of L_R. The shear force is positive when the algebraic sum of all vertical forces aft of the section is positive.

2.5.3 The actual shear force obtained from the longitudinal strength calculations may be corrected for the effect of local forces at the transverse bulkhead, if applicable.

2.6 Dynamic bending moments and associated shear forces

2.6.1 The dynamic bending moments, including wave and still water effects, specified here are applicable to all non-displacement mono-hull craft as defined in *Pt 1, Ch 2, 2.2 Definitions 2.2.14*.

2.6.2 The dynamic bending moment, due to slamming effects at amidships, is to be calculated using the following expression:

$$M_{DW} = F_f D_f |M_D| \text{ kNm}$$

where

$|M_D|$ = is taken to be the absolute value of the function, irrespective of signs

M_D = $51\Delta L_R(16a_v - 4a_b - 17a_s - 5)\, 10^{-3}$ kNm

Δ = displacement, in tonnes, as defined in *Pt 5, Ch 2, 2.2 Symbols 2.2.2*

F_f = - 1,0 for sagging (negative) moment

= 1,0 for hogging (positive) moment

D_f = 0 at aft end of L_R

= 1,0 between $0,4L_R$ and $0,65L_R$ from aft

= 0 at forward end of L_R

a_v = vertical acceleration at the LCG, in terms of g, as defined in *Pt 5, Ch 2, 3.2 Vertical acceleration 3.2.4*, *see also Pt 5, Ch 5, 1.1 Introduction 1.1.6*

a_b = vertical acceleration at forward end of L_R, in terms of g

a_s = vertical acceleration at aft end of L_R, in terms of g

If the values of a_b and a_s are unknown, the distributions given in *Pt 5, Ch 2, 3.2 Vertical acceleration 3.2.7* are applicable.

2.6.3 The bottom longitudinal amidships are additionally subjected to the following effective pressure, P_s:

$$P_s = 0,14P_{dl} + 8T \text{ kN/m}^2$$

where

P_{dl} is as defined in *Pt 5, Ch 2, 5.2 Impact pressure for non-displacement mode 5.2.1*. T is as defined in *Pt 3, Ch 1, 6 Definitions*.

2.6.4 The bottom plating amidships is subjected to the following additional effective pressure, P_t:

$$P_t = 0,175P_{dl} + 10T \text{ kN/m}^2$$

where

P_{dl} is as defined in *Pt 5, Ch 2, 5.2 Impact pressure for non-displacement mode 5.2.1*. T is as defined in *Pt 3, Ch 1, 6 Definitions*

2.6.5 The dynamic shear force, Q_{DW}, at any position along the craft is given by:

$$Q_{DW} = \frac{4K_f M_D}{L_R} \text{ kN}$$

where M_D is as defined in *Pt 5, Ch 5, 2.6 Dynamic bending moments and associated shear forces 2.6.2* and K_f is as defined in *Pt 5, Ch 5, 2.4 Wave shear force 2.4.1*.

Section 3
Hull girder load criteria for multi-hull craft

3.1 General

3.1.1 The vertical bending moments specified here are applicable to all multi-hull craft as defined in *Pt 1, Ch 2, 2.2 Definitions 2.2.15*.

3.1.2 L_R and T are as defined in *Pt 3, Ch 1, 6 Definitions*.

3.2 Vertical wave bending moments and associated shear forces

3.2.1 The vertical wave bending moments, M_{MW}, including wave and still water effects, at amidship is given by the following:

$$M_{MW} = F_f D_f M_M \text{ kN m}$$

where

M_M = $S_f G_f E_f C_{WP} L_S^{2,5} B_M$ kN m

C_{WP} = the waterplane area coefficient and is to be taken not less than 0,5

G_f = service group factor, *see Pt 1, Ch 2, 3.5 Service area restriction notations 3.5.5*

= 0,5 for G1 craft and Zone 3 craft

= 0,6 for G2 craft and Zone 2 craft

= 0,65 for G2A craft and Zone 1 craft

= 0,7 for G3 craft

= 0,8 for G4 craft

= 1,0 for G5 and G6 craft

S_f = 1,1 for passenger and cargo craft

= 1,15 for craft other than cargo and passenger craft

E_f = 0,125 for sagging moment

= 0,2 for hogging moment

F_f = - 1,0 for sagging (negative) moment

= 1,0 for hogging (positive) moment

D_f = 0 at aft end of L_R

= 1,0 between $0,4L_R$ and $0,65L_R$ from aft end of L_R

= 0 at forward end of L_R

B_M = total breadth of hulls or struts at LCG at the waterline, in metres, excluding tunnels

L_S = Rule length, L_R, in metres, for partially submerged hulls

= strut length, in metres, for fully submerged hulls

3.2.2 The wave shear force, Q_{MW}, at any position along the craft is given by:

$$Q_{MW} = \frac{3K_f M_M}{L_S} \text{ kN}$$

where M_M is as defined in *Pt 5, Ch 5, 3.2 Vertical wave bending moments and associated shear forces 3.2.1* and K_f is as defined in *Pt 5, Ch 5, 2.4 Wave shear force 2.4.1*.

3.3 Dynamic bending moments

3.3.1 The dynamic bending moments, including wave and still water effects, specified here are applicable to all non-displacement multi-hull craft as defined in *Pt 1, Ch 2, 2.2 Definitions 2.2.15*.

3.3.2 The dynamic bending moment, M_{MDW}, due to slamming effects at amidships is to be calculated using the following expression:

$$M_{MDW} = F_f D_f M_{MD} \text{ kNm}$$

where

M_{MD} = $52 \Delta L_S(20 a_v - 5) \times 10^{-3}$ kNm

F_f = - 1,0 for sagging (negative) moment

= 1,0 for hogging (positive) moment

D_f = 0 at aft end of L_R

= 1,0 between $0{,}4L_R$ and $0{,}65L_R$ from aft

= 0 at forward end of L_R

a_v = vertical acceleration at the LCG, in terms of g, as defined in *Pt 5, Ch 2, 3.2 Vertical acceleration 3.2.5* as appropriate, *see also Pt 5, Ch 5, 1.1 Introduction 1.1.6*

Δ = displacement, in tonnes, as defined in *Pt 5, Ch 2, 2.2 Symbols 2.2.2*

L_S is as defined in *Pt 5, Ch 5, 3.2 Vertical wave bending moments and associated shear forces 3.2.1*.

3.3.3 The bottom longitudinals amidships are additionally subjected to the following effective pressure, P_s:

$$P_s = 0{,}14P_{dl} + 8T \text{ kN/m}^2$$

where

P_{dl} is as defined in *Pt 5, Ch 2, 5.2 Impact pressure for non-displacement mode 5.2.1*. T is as defined in *Pt 3, Ch 1, 6 Definitions*.

3.3.4 The bottom plating amidships is subjected to the following additional effective pressure, P_t:

$$P_t = 0{,}175P_{dl} + 10T \text{ kN/m}^2$$

where

P_{dl} is as defined in *Pt 5, Ch 2, 5.2 Impact pressure for non-displacement mode 5.2.1*. T is as defined in *Pt 3, Ch 1, 6 Definitions*

3.3.5 The dynamic shear force, Q_{MDW}, at any position along the craft is given by:

$$Q_{MDW} = \frac{4K_f M_{MD}}{L_S} \text{ kN}$$

where M_{MD} is as defined in *Pt 5, Ch 5, 3.3 Dynamic bending moments 3.3.2*. and K_f as defined in *Pt 5, Ch 5, 2.4 Wave shear force 2.4.1*.

■ *Section 4*
Primary load criteria for multi-hull craft

4.1 General

4.1.1 For multi-hull craft, the strength of the cross deck structure is to be checked for the loadings specified in this Section, *see also Pt 5, Ch 5, 5.3 Primary load combinations applicable to the cross-deck structure of multi-hull craft*.

4.1.2 Other values may be used provided they are verified by model experiments, full scale measurements or any other generally accepted theories. Full details are to be submitted for appraisal.

4.1.3 L_{R} and T are as defined in *Pt 3, Ch 1, 6 Definitions*.

4.2 Global loads for multi-hull craft with partially submerged hulls

4.2.1 The twin hull transverse bending moment, M_{B}, about a longitudinal axis is given by:

$$M_{\text{B}} = G_{\text{f}} b\, \Delta\, a_v \text{ kNm}$$

where

a_{v} = the vertical acceleration as defined in *Pt 5, Ch 2, 3.2 Vertical acceleration*, *see also Pt 5, Ch 5, 1.1 Introduction 1.1.6*

b = transverse distance, in metres, between the centre of the two hulls

G_{f} = service group factor, *see Pt 1, Ch 2, 3.5 Service area restriction notations 3.5.5*

= 1,25 for G1 and G2 craft and Zone 2 craft and Zone 3 craft

= 1,35 for G2A craft and Zone 1 craft

= 1,50 for G3 craft

= 2,00 for G4 craft

= 2,50 for G5 and G6 craft

Δ = displacement, in tonnes, as defined in *Pt 5, Ch 2, 2.2 Symbols 2.2.2*

4.2.2 The twin hull torsional connecting moment, M_{T}, is given by:

$$M_{\text{T}} = G_{\text{f}}\, \Delta\, L_{\text{R}} a_v \text{ kNm}$$

where

G_{f} = service group factor, *see Pt 1, Ch 2, 3.5 Service area restriction notations 3.5.5*

= 0,63 for G1 and G2 craft and Zone 2 and Zone 3 craft

= 0,70 for G2A craft and Zone 1 craft

= 0,75 for G3 craft

= 1,00 for G4 craft

= 1,25 for G5 and G6 craft

Δ = displacement, in tonnes, as defined in *Pt 5, Ch 2, 2.2 Symbols 2.2.2*

L_{R} = Rule length, in metres, as defined in *Pt 3, Ch 1, 6 Definitions*

a_{v} = the vertical acceleration as defined in *Pt 5, Ch 2, 3.2 Vertical acceleration*, *see also Pt 5, Ch 5, 1.1 Introduction 1.1.6*

4.2.3 The vertical shear force, Q_{T}, at the centreline of the cross-deck structure between the twin hulls is given by:

$$Q_{\text{T}} = G_{\text{f}}\, \Delta\, a_v \text{ kN}$$

where

G_{f} = service group factor, *see Pt 1, Ch 2, 3.5 Service area restriction notations 3.5.5*

= 1,25 for G1 and G2 craft and Zone 2 and Zone 3 craft

= 1,35 for G2A craft and Zone 1 craft

= 1,50 for G3 craft

= 2,00 for G4 craft

= 2,50 for G5 and G6 craft

where

Δ = displacement, in tonnes, as defined in *Pt 5, Ch 2, 2.2 Symbols 2.2.2*

a_v = the vertical acceleration as defined in *Pt 5, Ch 2, 3.2 Vertical acceleration*, *see also Pt 5, Ch 5, 1.1 Introduction 1.1.6*

4.3 Global loads for multi-hull craft with fully submerged hulls

4.3.1 The design side force acting at mid-draught of the hull is given by:

$$F_{FS} = G_f T \Delta^{2/3} Y_1 Y_2 \text{ kN}$$

where

G_f = service group factor, *see Pt 1, Ch 2, 3.5 Service area restriction notations 3.5.5*

= 8,5 for G1 and G2 craft and Zone 2 craft and Zone 3 craft

= 9,4 for G2A craft and Zone1 craft

= 10,2 for G3 craft

= 13,6 for G4 craft

= 17,0 for G5 and G6 craft

Δ = displacement, in tonnes, as defined in *Pt 5, Ch 2, 2.2 Symbols 2.2.2*

Y_1 = 1,55 - 0,75tanh (Δ/11000)

Y_2 = 0,75 + 0,35tanh (1,64$L_S \Delta^{-1/3}$ - 6)

L_S = strut length, in metres, at waterline.

4.3.2 The lateral pressure acting on the outboard hull may be assumed to be constant and is given by:

$$P_{FS} = \frac{F_{FS}}{A_{FS}} \text{ kN/m}^2$$

where A_{FS} is the projected area, in m^2, of the struts with length L_S at waterline at draught T.

4.3.3 The design transverse bending moment, M_B, due to the side force is given as:

$$M_B = F_{FS}(F + 0,5T) \text{ kNm}$$

where F is the distance, in metres, from the waterline to the top of cross structure.

4.3.4 The twin hull torsional connecting moment, M_T, is given by:

$$M_T = G_f \Delta L_R a_v \text{ kNm}$$

where

G_f = service group factor, *see Pt 1, Ch 2, 3.5 Service area restriction notations 3.5.5*

= 0,63 for G1 and G2 craft and Zone 2 and Zone 3 craft

= 0,70 for G2A craft and Zone 1 craft

= 0,75 for G3 craft

= 1,00 for G4 craft

= 1,25 for G5 and G6 craft

Δ = displacement, in tonnes, as defined in *Pt 5, Ch 2, 2.2 Symbols 2.2.2*

a_v = the vertical acceleration as defined in *Pt 5, Ch 2, 3.2 Vertical acceleration*, *see also Pt 5, Ch 5, 1.1 Introduction 1.1.6*

where

L_R = Rule length, in metres, as defined in *Pt 3, Ch 1, 6 Definitions*

4.3.5 The vertical shear force, Q_T, at the centreline of the cross-deck structure between the twin hulls is given by:

$$Q_T = G_f \Delta a_v \text{ kN}$$

where

G_f = service group factor, *see Pt 1, Ch 2, 3.5 Service area restriction notations 3.5.5*

= 1,25 for G1 and G2 craft and Zone 2 and Zone 3 craft

= 1,35 for G2A craft and Zone 1 craft

= 1,50 for G3 craft

= 2,00 for G4 craft

= 2,50 for G5 and G6 craft

Δ = displacement, in tonnes, as defined in *Pt 5, Ch 2, 2.2 Symbols 2.2.2*

a_v = the vertical acceleration as defined in *Pt 5, Ch 2, 3.2 Vertical acceleration*, *see also Pt 5, Ch 5, 1.1 Introduction 1.1.6*

■ *Section 5*
Design criteria and load combinations

5.1 Hull girder design criteria for mono-hull craft

5.1.1 The Rule bending moment, M_R, and associated shear forces, Q_R, for non-displacement craft are to be determined as follows:

(a) The Rule bending moment, M_R, is to be taken as the greater of ($M_w + M_S$), as defined in *Pt 5, Ch 5, 2.2 Vertical wave bending moments* and *Pt 5, Ch 5, 2.3 Still water bending moments* and M_{DW}, as defined in *Pt 5, Ch 5, 2.6 Dynamic bending moments and associated shear forces*, taking into account the hogging and sagging conditions.

(b) The Rule shear forces, Q_R, are to be taken as the greater of ($Q_w + Q_S$), as defined in *Pt 5, Ch 5, 2.4 Wave shear force* and *Pt 5, Ch 5, 2.5 Still water shear force* and Q_{DW}, as defined in *Pt 5, Ch 5, 2.6 Dynamic bending moments and associated shear forces*, taking into account the hogging and sagging conditions.

5.1.2 The Rule bending moment, M_R, and associated shear forces, Q_R, for displacement craft are taken to be the greater of the following:

(a) The Rule bending moment, M_R, is to be taken as ($M_w + M_S$), as defined in *Pt 5, Ch 5, 2.2 Vertical wave bending moments* and *Pt 5, Ch 5, 2.3 Still water bending moments* , taking into account the hogging and sagging conditions.

(b) The Rule shear forces, Q_R, are to be taken as ($Q_w + Q_S$), as defined in *Pt 5, Ch 5, 2.4 Wave shear force* and *Pt 5, Ch 5, 2.5 Still water shear force* , taking into account the hogging and sagging conditions.

5.1.3 L_R and B are as defined in *Pt 3, Ch 1, 6 Definitions*. Γ and Δ are defined in *Pt 5, Ch 2, 2.1 Parameters to be used for the determination of load and design criteria 2.1.17* and *Pt 5, Ch 2, 2.2 Symbols 2.2.2* respectively.

5.2 Hull girder design criteria for multi-hull craft

5.2.1 The Rule bending moment, M_R, and associated shear forces, Q_R, for non-displacement craft are to be determined as follows:

(a) The Rule bending moment, M_R, is to be taken as the greater of M_{MW}, as defined in *Pt 5, Ch 5, 3.2 Vertical wave bending moments and associated shear forces* and M_{MDW}, as defined in *Pt 5, Ch 5, 3.3 Dynamic bending moments*, taking into account the hogging and sagging conditions.

(b) The Rule shear forces, Q_R, are to be taken as the greater of Q_{MW}, as defined in *Pt 5, Ch 5, 3.2 Vertical wave bending moments and associated shear forces* and Q_{MDW}, as defined in *Pt 5, Ch 5, 3.3 Dynamic bending moments*, taking into account the hogging and sagging conditions.

5.2.2 The Rule bending moment, M_R, and associated shear forces, Q_R, for displacement craft are taken to be the greater of the following:

(a) The Rule bending moment, M_R, is to be taken as M_{MW}, as defined in *Pt 5, Ch 5, 3.2 Vertical wave bending moments and associated shear forces*, taking into account the hogging and sagging conditions.
(b) The Rule shear forces, Q_R, are to be taken as Q_{MW}, as defined in *Pt 5, Ch 5, 3.2 Vertical wave bending moments and associated shear forces*, taking into account the hogging and sagging conditions.

5.2.3 L_R and B are as defined in *Pt 3, Ch 1, 6 Definitions*. Γ and Δ are defined in *Pt 5, Ch 2, 2.1 Parameters to be used for the determination of load and design criteria 2.1.17* and *Pt 5, Ch 2, 2.2 Symbols 2.2.2* respectively.

5.3 Primary load combinations applicable to the cross-deck structure of multi-hull craft

5.3.1 If the global load criteria given in this Chapter are utilised to check cross-deck strength against ductile failure modes involving gross deformation, the following load combinations are to be considered depending on heading of the craft:

(a) Head sea

$0{,}1M_B + M_R + 0{,}1\,M_T$

(b) Beam sea

$M_B + 0{,}1\,M_R + 0{,}2\,M_T$

(c) Quartering sea

$0{,}1M_B + 0{,}4\,M_R + M_T$

M_B, M_T and M_R are to be taken from *Pt 5, Ch 5, 4.2 Global loads for multi-hull craft with partially submerged hulls 4.2.1*, *Pt 5, Ch 5, 4.2 Global loads for multi-hull craft with partially submerged hulls 4.2.3* and *Pt 5, Ch 5, 5.2 Hull girder design criteria for multi-hull craft* for multi-hull craft with partially submerged hulls.

5.3.2 M_B, M_T and M_R are to be taken from *Pt 5, Ch 5, 4.3 Global loads for multi-hull craft with fully submerged hulls 4.3.1*, *Pt 5, Ch 5, 4.3 Global loads for multi-hull craft with fully submerged hulls 4.3.3* and *Pt 5, Ch 5, 5.2 Hull girder design criteria for multi-hull craft* for multi-hull craft with fully submerged hulls.

5.3.3 The strength calculations are, in general, to be conducted using the finite element analysis techniques with a three dimensional model.

■ *Section 6*
Loading guidance information

6.1 General

6.1.1 Sufficient information is to be supplied to every craft to enable the Master to arrange loading and ballasting in such a way as to avoid the creation of unacceptable stresses in the craft's structure.

6.1.2 This information is to be provided by means of a Loading manual and in addition, where required, by means of an approved loading instrument.

6.1.3 An Operational manual which contains the craft's assigned operational envelope is to be provided on board, *see Pt 1, Ch 2, 2 Scope of the Rules* and *Ch 1, 1 Background*.

6.2 Loading manuals

6.2.1 A Loading Manual is to be supplied to all craft where longitudinal strength calculations have been required, *see Pt 5, Ch 5, 1 General*. The Manual is to be submitted for approval in respect of strength aspects. Where both Loading Manual and loading instrument are supplied the Loading Manual must nevertheless be approved from the strength aspect. In this case the Manual is to be endorsed to the effect that any departures from these conditions in service are to be arranged on the basis of the loading instrument and the allowable local loadings shown in the Manual.

6.2.2 The Loading Manual is to be based on the final data of the craft and is to include well-defined lightweight distribution and buoyancy data.

6.2.3 Details of the loading conditions are to be included in the Manual as applicable.

6.2.4 The Loading Manual is also to contain the following:

(a) Values of actual and permissible still water bending moments and shear forces and where applicable limitations due to torsional loads.
(b) The allowable local loadings for the structure.
(c) Details of cargo carriage constraints imposed by the use of an accepted coating in association with a system of corrosion control.
(d) A note saying:

`Scantlings approved for minimum draught forward of ...m with ballast tanks No ... filled. In heavy weather conditions the forward draught is not to be less than this value. If, in the opinion of the Master, sea conditions are likely to cause regular slamming, then other appropriate measures such as change in speed, heading or an increase in draught forward may also need to be taken.'

6.2.5 Where alteration to structure, lightweight, cargo distribution or draught is proposed, revised information is to be submitted for approval.

6.3 Loading instrument

6.3.1 In addition to a Loading Manual, an approved type loading instrument is to be provided for craft when it is deemed necessary by Lloyds Register (hereinafter referred to as LR).

6.3.2 The loading instrument is to be capable of calculating shear forces and bending moments, and where necessary cargo torque, in any load or ballast condition at specified readout points and is to indicate the permissible values. The instrument is to be certified in accordance with LR's*Approval of Longitudinal Strength and Stability Calculation Programs*.

6.3.3 The instrument readout points are usually selected at the position of the transverse bulkheads or other obvious boundaries. As many readout points as considered necessary by LR are to be included, e.g. between bulkheads.

6.3.4 A notice is to be displayed on the loading instrument stating:

`Scantlings approved for minimum draught forward of ... m with ballast tanks No ... filled. In heavy weather conditions the forward draught is not be to less than this value. If, in the opinion of the Master, sea conditions are likely to cause regular slamming, then other appropriate measures such as change in speed, heading or an increase in draught forward may also need to be taken.'

6.3.5 Where alteration to structure, lightweight or cargo distribution is proposed, the loading instrument is to be modified accordingly and details submitted for approval.

6.3.6 The operation of the loading instrument is to be verified by the Surveyor upon installation and at Annual and Periodical Surveys as required in *Pt 1, Ch 3 Periodical Survey Regulations for Service Craft*. An Operation Manual for the instrument is to be verified as being available on board.

6.3.7 Where an onboard computer system having a strength computation capability is provided as an Owner's option, it is recommended that the system be certified in accordance with LR's document entitled *Approval of Longitudinal Strength and Stability Calculation Programs*. For systems having a stability computation capability and installed on a new ship, *see also Pt 1, Ch 2, 1.1 General 1.1.10*. For systems having a stability computation capability and installed on an existing craft, it is recommended that the system be certified in accordance with LR's document entitled, *Approval of Longitudinal Strength and Stability Calculation Programs*.

Contents

Section

Section 1
Application

1.1 General

1.1.1 The Rules apply to mono and multi-hull craft of normal form, proportions and speed. Although the Rules are, in general, for steel craft of all welded construction, other materials for use in hull construction will be specially considered on the basis of the Rules.

1.2 Interpretation

1.2.1 The interpretation of the Rules is the sole responsibility and at the sole discretion of Lloyd's Register (hereinafter referred to as 'LR'). Where there is any doubt regarding the interpretation of the Rules it is the Builders' and/or designers' responsibility to obtain clarification from LR prior to submission of plans and data for appraisal.

1.2.2 Where applicable, the Rules take into account unified requirements and interpretations established by the International Association of Classification Societies (IACS).

1.2.3 Attention is drawn to the fact that Codes of Practice issued by IMO contain requirements which are outside classification as defined in the Rules.

1.3 Equivalents

1.3.1 Alternative scantlings and arrangements may be accepted as equivalent to the Rule requirements. Details of such proposals are to be submitted for consideration in accordance with *Pt 3, Ch 1, 3 Equivalents*.

1.4 Symbols and definitions

1.4.1 The symbols and definitions for use throughout this Part are as defined within the appropriate Chapters and Sections.

Section 2
General requirements

2.1 General

2.1.1 Limitations with regard to the application of these Rules are indicated in the various Chapters for differing craft types.

2.2 Aesthetics

2.2.1 LR is not concerned with the general arrangement, layout and appearance of the craft; the responsibility for such matters remains with the Builders and/or designers to ensure that the agreed specification is complied with. LR is however concerned with the quality of workmanship, in this respect the acceptance criteria as required by Rules are to be complied with.

2.3 Constructional configuration

2.3.1 The Rules provide for the basic structural configurations for both single and multi-deck mono and multi-hull craft with multi-deck or a single deck hulls which include a double bottom, or a single bottom arrangement. The structural configuration may also include a single or multiple arrangement of cargo hatch openings, and side tanks.

2.3.2 The Rules provide for longitudinal and transverse framing systems.

2.3.3 Novel or other types of framing systems will be considered on the basis of the Rules.

2.4 Plans to be submitted

2.4.1 Plans covering the following items are to be submitted:

- Midship sections showing longitudinal and transverse material.
- Profile and decks.
- Shell expansion.
- Oiltight and watertight bulkheads.
- Propeller brackets.
- Double bottom construction.
- Pillars and girders.
- Aft end construction.
- Engine room construction.
- Engine and thrust seatings.
- Fore end construction.
- Hatch cover construction.
- Deckhouses and superstructures.
- Sternframe.
- Rudder, stock and tiller.
- Equipment.
- Loading Manuals, preliminary and final (where applicable).
- Scheme of corrosion control (where applicable).
- Ice strengthening.
- Welding schedule.
- Hull penetration plans.
- Support structure for masts, derrick posts or cranes.
- Bilge keels showing material grades, welded connections and detail design.
- Any special arrangements (e.g anchor deployment systems, submarine anchor pockets).

2.4.2 The following supporting documents are to be submitted:

- General arrangement.
- Capacity plan.
- Modes of operation for which the craft is designed (speeds corresponding to displacement and non-displacement mode as applicable).
- Lines plan or equivalent.
- Dry-docking plan.
- Towing and mooring arrangements.
- Sail/rigging plan, indicating loadings (as applicable to sailing craft).

2.4.3 The following supporting calculations are to be submitted:

- Equipment Number.
- Hull girder still water and dynamic bending moments and shear forces as applicable.
- Midship section modulus.
- Structural items in the aft end, midship and fore end regions of the craft.
- Preliminary freeboard calculation.

2.5 Novel features

2.5.1 Where the proposed construction of any part of the hull or machinery is of novel design, or involves the use of unusual material, or where experience, in the opinion of LR, has not sufficiently justified the principle or mode of application involved,

special tests or examinations before and during service may be required. In such cases a suitable notation may be entered in the *Register Book*.

2.6 Enhanced scantlings

2.6.1 Where the Owner decides to increase the scantlng of the bottom shell, side shell and deck plating of a newbuilding, then the craft will be eligible to be assigned the description note ***ES*** , *see Pt 1, Ch 2, 3.12 Descriptive notes*. For example, the descriptive note ***ES +1*** would indicate that an extra 1 mm of steel has been fitted to bottom shell, side shell and deck plating.

2.7 Direct calculations

2.7.1 Direct calculations may be specifically required by the Rules and may be required for craft having novel design features or in support of alternative arrangements and scantlings. LR may, when requested, undertake calculations on behalf of designers and make recommendations with regard to suitability of any required model tests.

2.7.2 Where direct calculations are proposed then the requirements of *Pt 3, Ch 1, 2 Direct calculations* are, in general, to be complied with.

2.8 Exceptions

2.8.1 Craft of unusual form, proportions or speed, intended for the carriage of special cargoes, or for special or restricted service, not covered specifically by the Rules, will receive individual consideration based on the general requirements of the Rules.

2.9 Advisory services

2.9.1 The Rules do not cover certain technical characteristics, such as stability, except as mentioned in *Pt 1, Ch 2, 1.1 General 1.1.11* and *Pt 1, Ch 2, 1.1 General 1.1.13*, trim, vibration (other than local stiff end flat panels, *see Ch 1, 5 Applicability of Classification Rules and Disclosure of Information*), docking arrangements, etc. The Committee cannot assume responsibility for these matters but is willing to advise upon them on request.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull and multi-hull craft of steel construction as defined in *Ch 1, 1 Background*.

1.2 General

1.2.1 This Chapter contains the general Rule requirements for the construction of steel craft using electric arc welding processes. Where alternative methods of construction are proposed, details are to be submitted for consideration by Lloyd's Register (hereinafter referred to as 'LR').

1.3 Symbols and definitions

1.3.1 The symbols and definitions used in this Chapter are defined in the appropriate Section.

1.4 Builder's facilities

1.4.1 The buildings used for production and storage are to be of suitable construction and equipped to provide the required environment, and are also to comply with any local or National Authority requirements.

1.4.2 The Surveyor is to be allowed unrestricted access during working hours to such parts of the Builder's establishment as may be necessary to ensure that the requirements of the Rules are being complied with.

1.5 Works inspection

1.5.1 Prior to the commencement of construction, the facilities are to be inspected to the satisfaction of the attending Surveyor. This will include the minimum quality control arrangements outlined in *Pt 6, Ch 2, 1.6 Quality control*.

1.5.2 The Surveyor is to be satisfied that the Builder has the organisation and capability to construct craft to the standards required by the Rules.

1.5.3 The Builder is to be advised of the result of the inspection and all deficiencies are to be rectified prior to the commencement of production.

1.5.4 Where structural components are to be assembled and welded by sub-contractors, the Surveyors are to inspect the sub-contractor's works to ensure that compliance with the requirements of this Chapter can be achieved.

1.6 Quality control

1.6.1 For compliance with *Pt 6, Ch 2, 1.5 Works inspection 1.5.2*, LR's methods of survey and inspection for hull construction and machinery installation are to include procedures involving the shipyard management, organisation and quality systems.

1.6.2 The extent and complexity of the quality systems will vary considerably depending on the size and type of craft and production output. LR will consider certification of the Builder in accordance with the requirements of one of the following systems:

(a) Quality Assurance System in accordance with an International or National Standard (i.e. ISO 9000 and BS ENISO 9001) with assessment and certification carried out by a nationally accredited body.

(b) LR's locally accepted Quality Control System - The Builder is implementing a documented Quality Control System which controls the following activities:

(i) Receipt storage and issue of materials, equipment etc.
(ii) Fabrication environment.
(iii) Weld procedures and welder performance.
(iv) Production fabrication.
(v) Inspection of production processes.
(vi) Installation of machinery and essential systems.
(vii) Fitting-out.
(viii) Tests and trials.
(ix) Drawings and document control.
(x) Records.

1.6.3 LR's involvement is only in that part of the system which controls the standards required to meet the classification requirements.

1.6.4 The `documented' quality control system will in general require the Builder to have written procedures that describe clearly and unambiguously how each of the activities specified in *Pt 6, Ch 2, 1.6 Quality control 1.6.2.(b)* is carried out, when it is carried out and by whom. These procedures will form part of the system manual which is also to contain a statement of management policy, organisation chart and statements of responsibilities. The manual is to be controlled in respect to the formal issue and revision.

1.6.5 Further details of LR's requirements are available on request from the local LR office.

1.7 Building environment

1.7.1 The craft is to be suitably protected during the building period from adverse weather and climatic conditions.

1.8 Storage areas

1.8.1 All materials are to be stored safely and in accordance with the manufacturer's requirements. Storage arrangements are to be such as to prevent deterioration through contact with heat, sunlight, damp, cold and poor handling.

1.8.2 All storage spaces provided by the Builder for welding consumables are to be suitable for maintaining them in good condition and are to be in accordance with the manufacturer's recommendations.

1.8.3 All materials are to be fully identifiable in the storage areas, and identification is to be maintained during issue to production.

1.8.4 Material suspected of being non-conforming is to be segregated from acceptable materials.

1.9 Materials handling

1.9.1 The Builder is to maintain purchasing documents containing a clear description of the materials ordered for use in hull construction and the standards to which the material must conform, together with the identification and certification requirements.

1.9.2 The Builder is to be responsible for ensuring that all incoming plates, sections, castings, components, fabrications and consumables and other materials used in the hull construction are inspected or otherwise verified as conforming to purchase order requirements.

1.9.3 The Builder is to have procedures for the inspection, storage and maintenance of Owner supplied materials and equipment.

1.9.4 The Builder is to record, on receipt, the manufacturing date, or use-by date of critical materials. Any materials which have a shelf life are to be used in order of manufacturing date to ensure stock rotation.

1.9.5 The Builder is to establish and maintain a procedure to ensure that materials and consumables used in the hull construction process are identified (by colour-coding and/or marking as appropriate) from arrival in the yard through to fabrication in such a way as to enable the type and grade to be readily recognised.

1.9.6 Where materials are found to be defective they are to be rejected in accordance with the Builder's quality control procedure.

1.10 Faults

1.10.1 All identified faults are to be recorded under the requirements of the quality control systems. Faults are to be classified according to their severity and are to be monitored during Periodical Survey.

1.10.2 Production faults are to be discussed with the attending Surveyor and a rectification scheme agreed. Deviations from the approved plans are to be locally approved by the attending Surveyor and a copy forwarded to the plan approval office for record purpose.

1.11 Inspection

1.11.1 On acceptance of a `Request for Services' the attending Surveyor is to inform the Builder of the key stages of the production that are to be inspected and the extent of the inspection to be carried out.

1.11.2 It is the Builder's responsibility to carry out required inspections in accordance with the accepted quality control system.

1.11.3 It is the Surveyor's responsibility to monitor the Builder's quality control records and carry out inspections at key stages and during periodic visits.

1.11.4 Adequate facilities are to be provided to enable the Surveyor to carry out a satisfactory inspection and to facilitate subsequent in-service maintenance. These are to include the provision of access holes in restricted spaces and removable deckhead and shipside linings, cabin soles, etc.

1.11.5 During inspections all deviations are to be dealt with in accordance with *Pt 6, Ch 2, 1.6 Quality control 1.6.4*.

1.12 Acceptance criteria

1.12.1 Classification is dependent upon the work being carried out in accordance with the approved plans and the requirements of an accepted quality control system.

1.12.2 The work is to be carried out to the satisfaction of the attending Surveyor. This will include the verification of the quality control documentation and the remedial action associated with all defects and deficiencies recorded.

1.12.3 Proposed deviations from the approved plans are subject to LR approval and in the first instance are to be discussed with the attending Surveyor. Where applicable, an amended plan is to be submitted to the plan appraisal office. Such deviations will be recorded as endorsements to the classification unless specifically agreed otherwise with the plan appraisal office.

1.12.4 Where the above requirements are met the attending Surveyor will arrange for the relevant certification to be issued.

1.13 Repair

1.13.1 Minor repairs are to be agreed with the attending Surveyor and a rectification scheme agreed with the Builder. The Builder is to incorporate details of the agreed repair procedures in the quality control system in accordance with *Pt 6, Ch 2, 1.6 Quality control 1.6.4*.

1.13.2 Repairs which affect the structural integrity are to be discussed with the Builder and the Builder's proposed rectification scheme is to be submitted to the plan appraisal office for consideration.

■ *Section 2* **Materials**

2.1 General

2.1.1 The materials used in the construction of the craft are to be manufactured and tested in accordance with the appropriate requirements of *Ch 3 Rolled Steel Plates, Strip, Sections and Bars* of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials.

2.1.2 All materials are to be manufactured at works which have been approved by LR for the type and, where appropriate, grade of steel which is being supplied and for the relevant steel production and processing route.

2.2 Grade of steel

2.2.1 The grade of steel, supply condition and its mechanical properties are to be indicated on the construction plans.

2.2.2 When plate material, intended for welded construction, will be subject to significant strains in a direction perpendicular to the rolled surfaces, it is recommended that consideration be given to the use of special plate material with specified through thickness properties, and tested in accordance with *Ch 3, 8 Plates with specified through thickness properties* of the Rule for Materials.

2.3 Steel castings and forgings

2.3.1 Where steel castings or forgings are used for sternframes, rudder frames, rudder stocks, propeller shaft brackets and other major structural items, they are to comply with *Pt 6, Ch 4 Scantling Determination for Multi-Hull Craft* or *Pt 6, Ch 5 Special Features*, as appropriate.

2.4 Mechanical properties for design

2.4.1 The scantlings determined within this Part of the Rules assume that mild steel has the following mechanical properties:

	N/mm^2
Yield strength (minimum)	235
Tensile strength	400 - 490
Modulus of elasticity	200×10^3

2.4.2 Steel having a specified minimum yield stress of 235 N/mm^2 (24 kgf/mm^2) is regarded as mild steel. Steel having a higher specified minimum yield stress is regarded as higher tensile steel.

2.4.3 The requirements for global strength considerations in craft incorporating higher tensile steel materials are to be based on a higher tensile steel concentration factor, η_{HTS}, as given in *Table 2.2.1 Higher tensile steel concentration factor η_{HTS}* .

Table 2.2.1 Higher tensile steel concentration factor η_{HTS}

Specified minimum yield stress in N/mm^2	η_{HTS}
235	1,000
265	0,964
315	0,956
340	0,934
355	0,919
Note Intermediate values may be obtained by linear interpolation.	

2.4.4 The local scantling requirements of higher tensile steel plating, longitudinals, stiffeners and girders may be based on a k_s factor determined as follows:

$$k_s = \frac{235}{\sigma_s}$$

or 0,66 whichever is the greater

where

σ_s = specified minimum yield strength of material in N/mm^2

2.4.5 For the application of the requirements of *Pt 6, Ch 2, 2.4 Mechanical properties for design 2.4.3* and *Pt 6, Ch 2, 2.4 Mechanical properties for design 2.4.4* special consideration will be given to steel where $\sigma_s > 355$ N/mm^2. Where such steel grades are used in areas which are subject to fatigue loading the structural details are to be verified using fatigue design assessment methods.

2.5 Corrosion protection

2.5.1 Corrosion prevention requirements are to be in accordance with Chapter 15 of the Rules for Materials.

2.5.2 All steelwork, except inside integral fuel tanks, is to be suitably protected against corrosion. This may be by coating or, where applicable, by a system of cathodic protection.

2.5.3 Steelwork is to be suitably cleaned and cleared of millscale before the application of any coating. It is recommended that blast cleaning, or other equally effective means, be employed for this purpose.

2.5.4 Where a cathodic protection system is fitted, plans showing the proposed layout of anodes and hull penetrations are submitted in accordance with *Ch 15 Corrosion Prevention* of the Rules for Materials.

2.6 Paints and coatings

2.6.1 The hull is to be protected against corrosion by a suitable protective coating.

2.6.2 Prefabrication primers are to be approved in accordance with *Ch 15 Corrosion Prevention* of the Rules for Materials.

2.6.3 Paints or other coatings are to be suitable for the intended purpose in the locations where they are to be used, and where appropriate, approved in accordance with *Ch 15 Corrosion Prevention* of the Rules for Materials. Coatings are to be of adequate film thickness, applied in accordance with the paint manufacturer's specification.

2.6.4 Integral fuel tanks are to be cleaned and dried, after testing, and then treated with a suitable coating, in accordance with the manufacturer's recommendations.

2.6.5 Paints, varnishes and similar preparations having a nitro-cellulous or other highly flammable base are not to be used in accommodation or machinery spaces.

2.7 Galvanic action

2.7.1 Where bimetallic connections are made, involving dissimilar metals, measures are to be incorporated to preclude galvanic corrosion. In order to prevent galvanic corrosion, special attention is to be given to the penetrations of, and connections to the hull, bulkheads and decks by piping and equipment where dissimilar materials are involved.

2.8 Bimetallic connections

2.8.1 The design shall ensure that the location of all bimetallic connections allows for regular inspection and maintenance of the joints and penetrations during service.

2.9 External immersed areas

2.9.1 For the deferment of dry-docking or where an **IWS** (In-Water Survey) notation is to be assigned protection of the underwater portion of the hull is to be provided by means of a suitable high resistance paint applied in accordance with the manufacturer's requirements. Details of the high resistance paint are to be submitted for information.

2.10 External cathodic protection

2.10.1 Where an impressed current cathodic protection (ICCP) system is fitted, plans showing the proposed layout of anodes, reference cells, wiring diagram and the means of bonding-in of the rudder and propeller, are to be submitted. ICCP requirements are to be in accordance with *Ch 15 Corrosion Prevention* of the Rules for Materials.

2.10.2 The arrangement for glands, where cables pass through the shell, are to include a small cofferdam. Cables to anodes are not to be led through tanks containing low flash point oils.

2.11 Protection of ballast spaces

2.11.1 Cathodic protection may be used in association with coatings for the protection of ballast spaces, *see Ch 15 Corrosion Prevention* of the Rules for Materials.

2.11.2 The anodes are to be of approved design and sufficiently rigid to avoid resonance in the anode support. Steel cores are to be fitted, and these are to be so designed as to retain the anode even when the latter is wasted.

2.11.3 Anodes are to be attached to the structure in such a way that they remain secure both initially and during service. The following methods of attachment would be acceptable:

(a) Steel core connected to the structure by continuous welding of adequate section.

(b) Steel core bolted to separate supports, provided that a minimum of two bolts with lock nuts are used at each support. The separate supports are to be connected to the structure by continuous welding of adequate section.

(c) Approved means of mechanical clamping.

2.11.4 Anodes are to be attached to stiffeners, or may be aligned in way of stiffeners on plane bulkhead plating, but they are not to be attached to the shell. The two ends are not to be attached to separate members which are capable of relative movement.

2.11.5 Where cores or supports are welded to the main structure, they are to be kept clear of the toes of brackets and similar stress raisers. Where they are welded to asymmetrical stiffeners, they are to be connected to the web with the welding kept at least 25 mm away from the edge of the web. In the case of stiffeners or girders with symmetrical face plates, the connection may be made to the web or to the centreline of the face plate but well clear of the free edges. However, it is recommended that anodes are not fitted to face plates of higher tensile steel longitudinals.

2.12 Deck coverings

2.12.1 Where plated decks are sheathed with wood, the sheathing is to be efficiently attached to the deck, caulked and sealed, to the satisfaction of the Surveyor in accordance with the approved drawings.

2.12.2 Deck coverings in the following positions are to be of a type which will not readily ignite when used on decks:

(a) Forming the crown of machinery or cargo spaces within accommodation spaces of cargo craft.

(b) Within accommodation spaces, control stations, stairways and corridors of passenger craft.

2.13 Corrosion margin

2.13.1 The scantlings determined from the formulae provided in the Rules assume that the materials used are selected, manufactured and protected in such a way that there is negligible loss in strength by corrosion.

2.13.2 Where steel is not protected against corrosion by painting or other approved means, further consideration of the scantlings is required.

2.14 Fracture control

2.14.1 Construction procedures, materials and welding are to be in accordance with the requirements of this Chapter such that stress corrosion cracking is avoided.

2.14.2 High local stresses are to be avoided by the use of suitable design detail. *See also* LR's *Guidance Notes for Structural Details.*

2.14.3 The resistance to fracture is controlled, in part, by the notch toughness of the steel used in the structure. Steels with different levels of notch toughness are specified in *Rules for the Manufacture, Testing and Certification of Materials, July 2021*. The grade of steel to be used is, in general, related to the thickness of the material and the stress pattern associated with its location.

2.14.4 Where tee or cruciform connections employ full penetration welds, and the plate material is subject to significant strains in a direction perpendicular to the rolled surfaces, it is recommended that consideration be given to the use of special plate material with specified through thickness properties, as detailed in *Ch 3, 8 Plates with specified through thickness properties*of the Rules for Materials.

2.14.5 For craft operating for long periods in low air temperature the material of exposed structures will, in general, be specially considered.

■ *Section 3*
Procedures for welded construction

3.1 General

3.1.1 Except as otherwise indicated below, all welded construction is to be conducted in accordance with the requirements specified in *Ch 13 Requirements for Welded Construction* of the Rules for Materials.

3.2 Information to be submitted

3.2.1 The plans and information submitted for approval are to clearly indicate details of the welded connections of the main structural members, including the type, disposition and size of welds.

3.3 Defined practices and welding sequence

3.3.1 The final boring out of propeller brackets and sterntubes and the fit-up and alignment of rudder bearings and jet units are to be carried out after the major part of the welding of the aft end of the craft is complete. The contacts between rudder stocks and propeller shafts with bearings are to be checked before the final mounting.

3.4 Structural arrangements and access

3.4.1 Ceilings, cabin sole, side and overhead linings are to be secured in such a manner as to be easily removed for the maintenance and inspection of the structure below.

3.5 Inspection and non-destructive examination

3.5.1 Inspection of welded construction is to be conducted in accordance with the requirements specified in *Ch 13 Requirements for Welded Construction* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2021*, and the general NDE requirements as per *Ch 1, 5.1 General NDE requirements* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2021*.

3.5.2 Checkpoints examined at the pre-fabrication stage are to include ultrasonic testing on examples of the stop/start points of automatic welding and magnetic particle inspections of weld ends.

3.5.3 Typical locations for volumetric examination and number of checkpoints to be taken are shown in *Table 2.3.1 Non-destructive examinations of welds*. A list of the proposed items to be examined is to be submitted for approval.

3.5.4 Alternative proposals to *Table 2.3.1 Non-destructive examinations of welds* will be considered on a case by case basis for example, implementing a statistical approach based on historical data and current trends, or implementing an enhanced quality assurance process scheme.

Table 2.3.1 Non-destructive examinations of welds

Volumetric non-destructive examinations - Recommended extent of testing		
Item	Location	Checkpoints, *see* Notes 1,2 and 4 (these are common to all listed item locations)
Intersections of butt and seams of fabrication and section welds	Throughout: • hull envelope • longitudinal and transverse bulkheads • inner bottom and hopper bottom	Checkpoints shall be taken at these locations; the summation of checkpoint lengths examined at intersections is to be 0,2*L*, where *L* is the overall length of the ship in metres.
Butt welds in plating	Throughout	1 m in 100 m, *see* Note 3
Seam welds in plating	Throughout	1 m in 200 m, *see* Note 3
Butts in longitudinals	Hull envelope within 0,4*L* amidships Hull envelope outside 0,4*L* amidships	1 in 40 welds 1 in 30 welds
Bilge keel butts	Throughout	1 in 40 welds
Structural items when made with full penetration welding as follows:	Throughout	1 m in 60 m

• connection of stool and bulkhead to lower stool shelf plating • vertical corrugations to an inner bottom • hopper knuckles • sheerstrake to deck stringer • hatchways coaming to deck		
Note 1. The length of each checkpoint is to be between 0,3m and 0,5m, where the length of weld permits. Note 2. For checkpoints at intersections the measured dimension of length is to be in the direction of the butt weld. *See Figure 2.3.1 Inspection of checkpoints located on longitudinal stiffeners* to *Figure 2.3.3 Checkpoint positions in way of radiography and ultrasonic inspection on deck plating* Note 3. Checkpoints in butt welds and seam welds are in addition to those at intersections. Note 4. The NDE checkpoint locations are not to be indicated on the blocks prior to the welding taking place, nor is any special treatment to be given at these locations.		

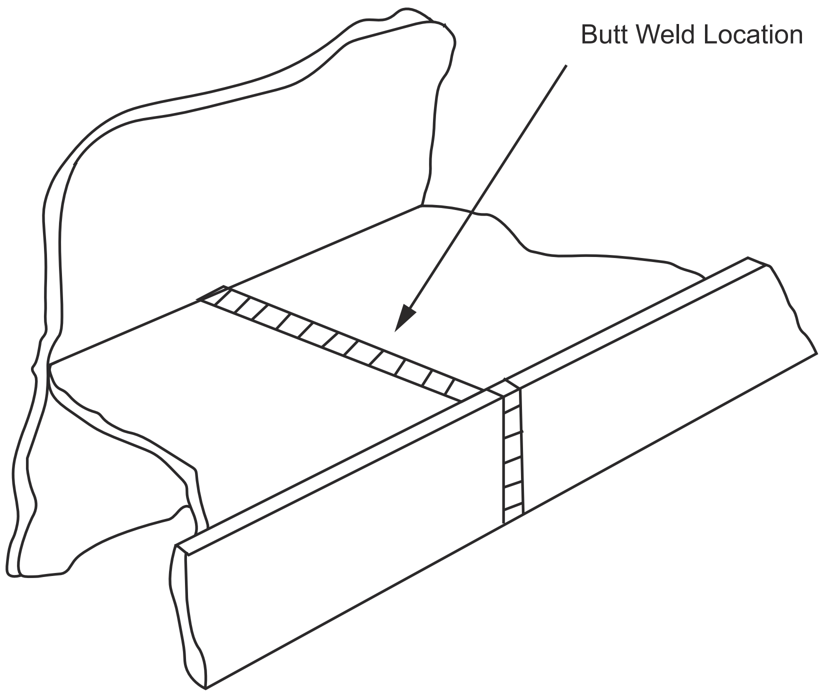
3.5.5 Any checkpoint which contains a rejectable weld discontinuity shall be repaired, as appropriate, and retested. Furthermore, volumetric NDE shall be increased by an additional one checkpoint for each checkpoint failure, to be chosen at random by the Surveyor. This additional checkpoint is supplementary to the repaired/retested location.

3.5.6 Systematic defects or repetitive defects shall be investigated, rectified, and retested where appropriate. The extent of NDE checkpoints shall be increased in way of the areas, weld types or intersections, where the systematic or repeated defects are observed, by an additional 50 per cent of the affected item (listed in Item column of *Table 2.3.1 Non-destructive examinations of welds*, to determine the weld quality.

3.5.7 If there is evidence to suggest the overall welding quality is not of a satisfactory nature, then a further NDE checkpoint regime, and enhanced quality assurance process, shall be applied. The fabricator shall present to the Surveyor the additional measures and regime to be implemented.

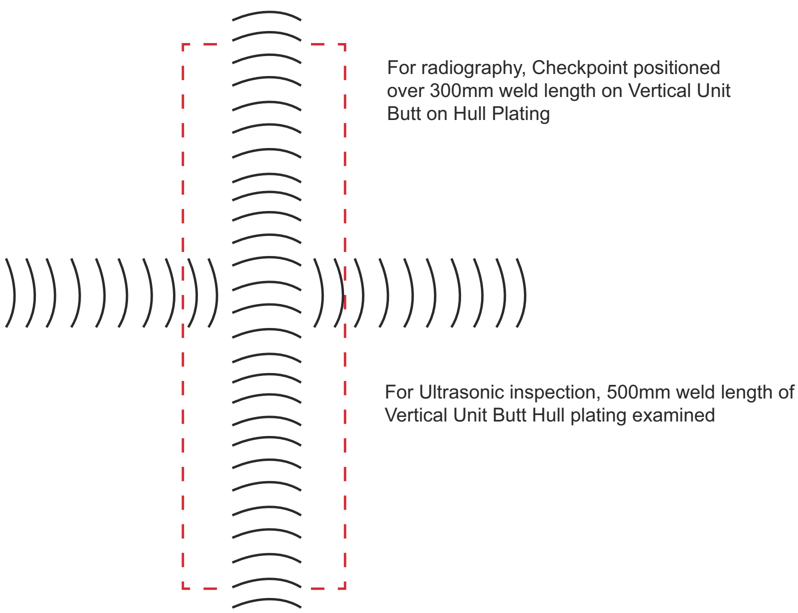
3.5.8 If cracks of any type or size are detected, then *Pt 6, Ch 2, 3.5 Inspection and non-destructive examination 3.5.5* and *Pt 6, Ch 2, 3.5 Inspection and non-destructive examination 3.5.6* shall apply.

3.5.9 Isolated gas pores, slag inclusions, or metallic inclusions shall not be considered as systematic defects, however, they must be assessed individually with respect to the applicable acceptance criteria within LR Rules, and *Pt 6, Ch 2, 3.5 Inspection and non-destructive examination 3.5.5* shall apply. All other defect types when repeatedly observed shall be considered as systematic defects, and *Pt 6, Ch 2, 3.5 Inspection and non-destructive examination 3.5.6* shall apply.



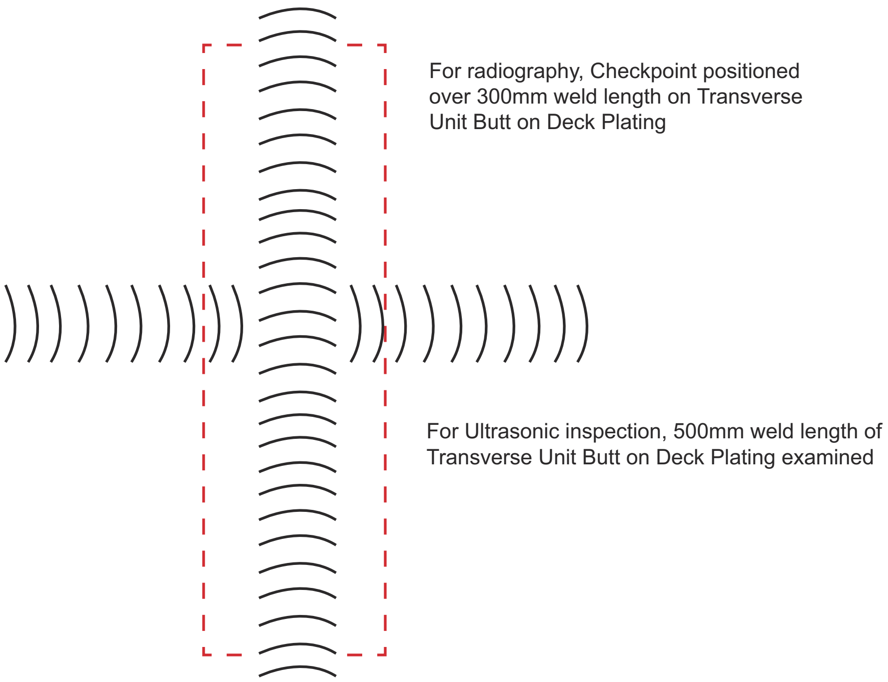
The length of butt welds located at checkpoints on longitudinal stiffeners may be less than 300 mm for radiography or 500 mm for ultrasonic inspection. In such cases inspect as much of the welds as access permits.

Figure 2.3.1 Inspection of checkpoints located on longitudinal stiffeners



Note for illustration, drawing shows checkpoint in vertical butt direction. For seam welds, the checkpoint location may lay in the horizontal direction.

Figure 2.3.2 Checkpoint positions in way of radiography and ultrasonic inspection on hull plating



Note for illustration, drawing shows checkpoint in vertical butt direction. For seam welds, the checkpoint location may lay in the horizontal direction.

Figure 2.3.3 Checkpoint positions in way of radiography and ultrasonic inspection on deck plating

3.6 Acceptance criteria

3.6.1 The surfaces of all finished welds are to be reasonably smooth and substantially free from undercut and overlap. Care is to be taken to ensure that the specified dimensions of welds have been achieved and that both excessive reinforcement and underfill of welds are avoided.

3.6.2 The acceptance criteria are to be in accordance with the appropriate Tables contained within *Ch 13, 2 Specific requirements for ship hull structure and machinery* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2021*.

■ *Section 4* Joints and connections

4.1 General

4.1.1 Requirements are given in this Chapter for welding connection details, aluminium/steel transition joints, steel/wood connection, riveting of light structure and chemical bonding.

4.1.2 Welded joints are to be detailed such that crevices or inaccessible pockets capable of retaining dirt or moisture are avoided. Where cavities are unavoidable, they are to be sealed by welding or protective compounds or made accessible for inspection and maintenance.

4.2 Weld symbols

4.2.1 Weld symbols, where used, are to conform to a recognised National or International Standard. Details of such Standards are to be indicated on the welding schedule, which is to be submitted for appraisal.

4.3 Welding schedule

4.3.1 A welding schedule containing not less than the following information is to be submitted:

(a) Weld throat thickness or leg lengths.
(b) Grades, tempers, and thicknesses of materials to be welded.
(c) Locations, types of joints and angles of abutting members.
(d) Reference to welding procedures to be used.
(e) Sequence of welding of assemblies and joining up of assemblies.

4.4 Butt welds

4.4.1 All structural butt joints are to be made by means of full penetration welds and, in general, the edges of plates to be joined by welding are to be bevelled on one or both sides of the plates. Full details of the proposed joint preparation are to be submitted for approval, *see also Pt 6, Ch 2, 4.23 Triaxial stress considerations*.

4.4.2 Where butt welds form a T-junction, the leg of the T is, where practicable, to be completed first including any back run. During the welding operation special attention is to be given to the completion of the weld at the junction, which is to be chipped back to remove crater cracks, etc. before the table is welded.

4.5 Fillet welds

4.5.1 The throat thickness of fillet welds is to be not less than:

$$\text{Throat thickness} = t_{\text{p}} \times \text{weld factor} \times \left(\frac{d}{s}\right) mm$$

where

s = the length, in mm, of the fillet that is fully formed and weld clear of any end dressing, as illustrated in *Figure 2.4.1 Weld dimensions and types*.

d = the distance between successive weld fillet, in mm

t_{p} = plate thickness, in mm, on which weld fillet size is based, *see Pt 6, Ch 2, 4.5 Fillet welds 4.5.5*

For weld fillet dimensions, *see Figure 2.4.1 Weld dimensions and types*.

Weld factors are given in *Table 2.4.1 Weld factors*.

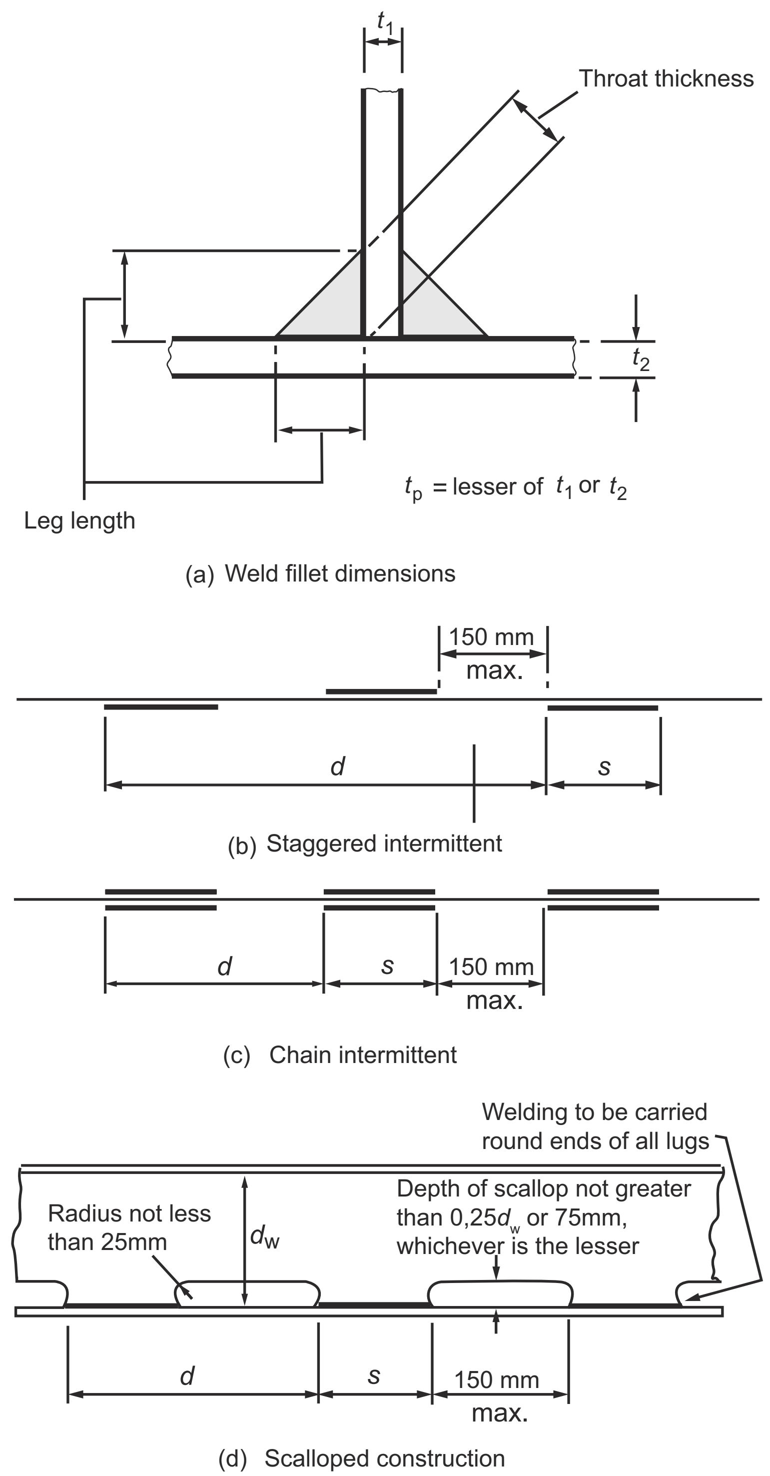


Figure 2.4.1 Weld dimensions and types

Table 2.4.1 Weld factors

Item		Weld Factor	Remarks
(1)	General application:		except as required below

	Shell envelope boundary, including sea chests and hull penetrations	Full penetration	For hull penetrations, fitted with a flange or other support, equivalent arrangements may be considered.
	Watertight plate boundaries	0,34	
	Non-tight plate boundaries	0,13	
	Longitudinals, frames, beams,	0,10	
	and other secondary members to shell, deck or	0,13	in tanks
	bulkhead plating	0,21	in way of end connections
	Panel stiffeners	0,10	
	Overlap welds generally	0,27	
(2)	Bottom construction:		
	Non-tight centre girder: to keel	0,27	
	to inner bottom	0,21	no scallops
	Non-tight boundaries of floors, girders and brackets	0,21	in way of 0,1 x span at ends
		0,27	in way of brackets at lower end of main frame
	Watertight bottom girders	0,34	
	Connection of girder to inner bottom in way of longitudinal bulkheads supported on inner bottom	0,44	
	Inner bottom longitudinals, or face flat to floors	0,13	
	reverse frames		
	Connection of floors to inner bottom where bulkhead is supported on tank top. The supporting floors are to be continuously welded to the inner bottom	0,44	Weld size based on floor thickness Weld material compatible with floor material
(3)	Hull framing:		
	Webs of web frames and stringers:		
	to shell	0,16	
	to face plate	0,13	
(4)	Decks and supporting structure:		
	Weather deck plating to shell	0,44	
	Other decks to shell and bulkheads	0,21	generally continuous
	(except where forming tank boundaries)		
	Webs of cantilevers to deck and to shell in way of root bracket	0,44	
	Webs of cantilevers to face plate	0,21	
	Girder webs to deck clear of end brackets	0,10	
	Girder webs to deck in way of end brackets	0,21	
	Web of girder to face plate	0,10	
	Pillars: fabricated	0,10	

	end connections	0,34	
	end connections (tubular)	full penetration	
	Girder web connections and brackets in way of pillar heads and heels	0,21	continuous
(5)	Bulkheads and tank construction:		
	Plane and corrugated watertight bulkhead boundary at bottom, bilge, inner bottom, deck and connection to shelf plate, where fitted	0,44	weld size to be based on thickness of bulkhead weld material to be compatible with bulkhead plating material
	Secondary members, where acting as pillars	0,13	
	Non-watertight pillar bulkhead boundaries	0,13	
	Perforated flats and wash bulkhead boundaries	0,10	
	Deep tank horizontal boundaries at vertical corrugations	full penetration	
(6)	Structure in machinery space:		
	Centre girder to keel and inner bottom	0,27	no scallops to inner bottom
	Floors to centre girder in way of engine thrust bearers	0,27	
	Floors and girders to shell and inner bottom	0,21	
	Main engine foundation girders:		
	to top plate to hull structure	deep penetration to depend on design	edges to be prepared with maximum root $0{,}33t_p$ deep penetration generally
	Floors to main engine foundation girders	0,27	
	Brackets, etc. to main engine foundation girders	0,21	
	Transverse and longitudinal framing to shell	0,13	
(7)	Superstructures and deckhouses:		
	Connection of external bulkheads to deck	0,34	1st and 2nd tier erections elsewhere
		0,21	
	Internal bulkheads	0,13	
(8)	Steering control systems:		
	Rudder:		
	Fabricated mainpiece and mainpiece to side plates and webs	0,44	
	Slot welds inside plates	0,44	
	Remaining construction	0,21	
	Fixed and steering nozzles:		
	Main structure	0,44	
	Elsewhere	0,21	
	Fabricated housing and structure of thruster units, stabilisers, etc.:		
	Main structure	0,44	

	Elsewhere	0,21	
(9)	Miscellaneous fittings and equipment:		
	Rings for manhole type covers, to deck or bulkhead	0,34	
	Frames of shell and weathertight bulkhead doors	0,34	
	Stiffening of doors	0,21	
	Ventilator, air pipes, etc. coamings to deck	0,34	Load Line Position 1 and 2
		0,21	elsewhere
	Ventilator, etc. fittings	0,21	
	Scuppers and discharges, to deck	0,44	
	Masts, crane pedestals, etc. to deck	0,44	full penetration welding may be required
	Deck machinery seats to deck	0,21	generally
	Mooring equipment seats	0,21	generally, but increased or full penetration may be required
	Bulwark stays to deck	0,21	
	Bulwark attachment to deck	0,34	
	Guard rails, stanchions, etc. to deck	0,34	
	Bilge keel ground bars to shell	0,34	continuous fillet weld, minimum throat thickness 4 mm
	Bilge keels to ground bars	0,21	light continuous or staggered intermittent fillet weld, minimum throat thickness 3 mm
	Fabricated anchors	full penetration	

4.5.2 The length, in mm, of any weld fillet in any intermittent welding arrangementis to be at least $10t_p$ or 40 mm, whichever is the greater but need not exceed 75mm.

4.5.3 For ease of welding, it is recommended that the ratio of the web height to the flange breadth is greater than or equal to 1,5, (*see Figure 2.4.2 Web height/flange breadth ratio*).

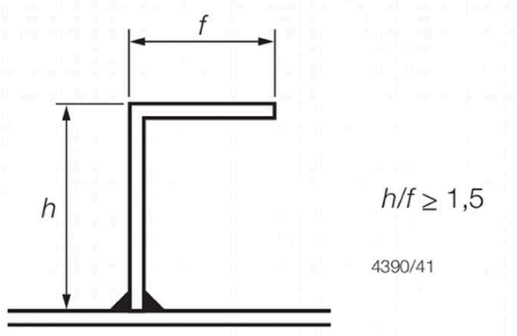


Figure 2.4.2 Web height/flange breadth ratio

4.5.4 The leg length of the weld is to be not less than $\sqrt{2}$ times the specified throat thickness.

4.5.5 The plate thickness t_p to be used in *Pt 6, Ch 2, 4.5 Fillet welds 4.5.1* is generally to be that of the thinner of the two parts being joined. Where the difference in thickness is considerable, the size of fillet weld will be specially considered.

4.6 Throat thickness limits

4.6.1 The throat thickness limits given in *Table 2.4.2 Throat thickness limits* are to be complied with.

Table 2.4.2 Throat thickness limits

Item	Throat thickness mm	
	Minimum	Maximum
(1) Double continuous welding	$0,21t_p$	$0,44t_p$
(2) Intermittent welding	$0,27t_p$	$0,44t_p$ or 4,5
(3) All welds, overriding minimum:		
(a) Plate thickness $t_p \leq 7,5$ mm		
Hand or automatic welding	3,0	—
Automatic deep penetration welding	3,0	—
(b) Plate thickness $t_p \geq 7,5$ mm		
Hand or automatic welding	3,25	—
Automatic deep penetration welding	3,0	—

Note 1. In all cases the limiting value is to be taken as the greatest of the applicable values above.

Note 2. Where t_p exceeds 25 mm, the limiting values may be calculated using a notional thickness equal to 0,4 (t_p + 25) mm.

Note 3. The maximum throat thicknesses shown are intended only as a design limit for the approval of fillet welded joints. Any welding in excess of these limits is to be to the Surveyor's satisfaction.

4.6.2 Where the throat thickness calculated in *Pt 6, Ch 2, 4.5 Fillet welds 4.5.1* is less than the overriding minimum value, as required by *Table 2.4.2 Throat thickness limits*, the limiting value is to be taken as the greater of the two. The upper limit for the throat thickness is, in general, to be as required by *Table 2.4.2 Throat thickness limits*. Throat thicknesses above this limit will be specially considered.

4.7 Double continuous fillet welding

4.7.1 Where double continuous fillet welding is proposed the throat thickness is to be in accordance with *Pt 6, Ch 2, 4.5 Fillet welds 4.5.1* taking $\left(\frac{d}{s}\right)$ equal to 1.

4.7.2 The impact area referred to in *Pt 6, Ch 2, 4.7 Double continuous fillet welding 4.7.4*, *Pt 6, Ch 2, 4.8 Intermittent fillet welding (staggered/chain) 4.8.1* and *Pt 6, Ch 2, 4.9 Single sided fillet welding 4.9.1* is defined as the area of the hull that, in normal design operation of the craft, will be subject to loads of sufficient magnitude and velocity for slamming to occur on a regular basis. Areas where conditions for slamming occur incidentally are not considered as impact areas.

4.7.3 The slamming zone area referred to in *Pt 6, Ch 2, 4.7 Double continuous fillet welding 4.7.2* is defined as the region where the operational non-displacement mode pressures exceed the operational displacement mode pressures.

4.7.4 Double continuous fillet welding is to be adopted in the following locations and may be used elsewhere if desired:

(a) Boundaries of weathertight decks and erections, including hatch coamings, companionways and other openings.
(b) Boundaries of tanks, watertight compartments and gastight compartments or in spaces or locations where condensation, spray or leakage water can accumulate.
(c) Main engine seatings.
(d) Bottom framing structure in way of machinery and jet room spaces of high speed craft as appropriate.
(e) The side and bottom shell structure in the impact area of high speed craft.
(f) The underside of the cross-deck structure in the impact area of high speed multi-hull craft.

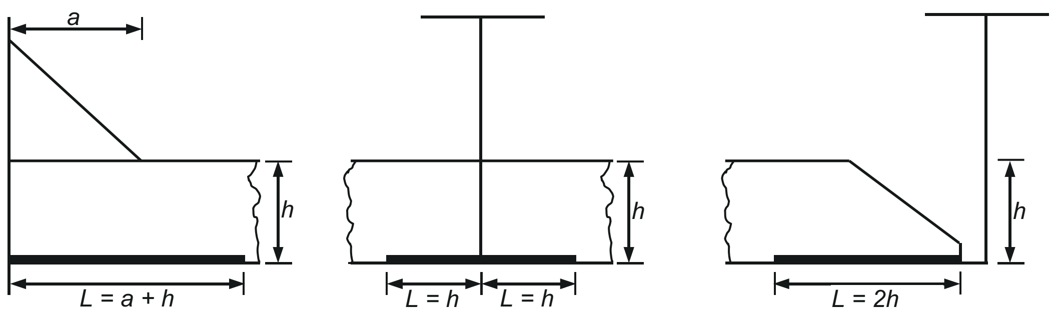
(g) Structure in way of ride control systems, stabilisers, foils, lifting devices, thrusters, bilge keels, foundations and other areas subject to high stresses.
(h) The shell structure in the vicinity of the propeller blades.
(i) Stiffening members to plating in way of end connections scallops and of end brackets to plating in the case of lap connections,
(j) Primary and secondary members to plating in way of end connections, and end brackets to plating in the case of lap connections.
(k) Face flats to webs of built-up/fabricated stiffening members in way of knees/end brackets and for a distance beyond such knees/end brackets of not less than the web depth of stiffener in way.
(l) Locations where double continuous welding is required to qualify assumptions used in structural calculations, e.g. weld of girder flange in way of large cutout in the web.

4.7.5 In all locations where double continuous fillet welds are required, the fillet welds shall be continued around the ends of stiffeners or cut-outs to seal all edges.

4.7.6 Where intermittent welding is permitted, the length of double continuous fillet welding required in way of primary and secondary member end connections to plating is as shown in *Figure 2.4.3 Extent of double continuous welding at end connections of primary and secondary members* and is not to be less than the greater of the following:

- the web depth of the smaller stiffening member extending either side of a stiffener crossing (weld length is required on both sides of the crossing members);
- twice the height of the stiffening member extending from either end of the stiffener if the stiffener is sniped;
- the height of the stiffening member plus the leg length of the attached bracket if the stiffener is bracketed; or
- 0,1 x stiffener span.

4.7.7 Proposals to reduce the double continuous weld lengths for secondary members may be specially considered provided that supporting documentation is submitted which considers effects such as strength, stiffness and dynamic loading frequency and other fatigue aspects.



h = secondary member depth
a = bracket arm length
L = required depth of double continuous weld. In no case is *L* to be less than 0,1 x stiffener span

Figure 2.4.3 Extent of double continuous welding at end connections of primary and secondary members

4.8 Intermittent fillet welding (staggered/chain)

4.8.1 Staggered or chain intermittent welding may be used, outside of the impact area in the side and bottom shell or the underside of the crossdeck structure of high speed craft. Supporting evidence is to be provided and agreed by LR demonstrating that no intermittent welding is applied in the impact areas of high speed craft, *see* Lloyd's Register Guidance Note – *Extent of double continuous welding for special service craft*. Consideration should be given to the relevant service area notation, service type notation and craft type notation.

4.9 Single sided fillet welding

4.9.1 Continuous single sided fillet welding may be used in lieu of intermittent fillet welding (staggered and chain), outside of the impact area in the bottom shell or crossdeck structure of high speed craft.

4.10 Connections of primary structure

4.10.1 Depending on the structural design of the joint and design loads on the primary member, full penetration welding of flanges and web plates may be required to attain full section properties in the end connections of primary members. *See also Pt 6, Ch 3, 1.22 Primary member end connections*. Otherwise weld factors for the connections of primary structure are given in *Table 2.4.1 Weld factors*.

4.10.2 The weld connection to shell, deck or bulkhead is to take account of the material lost in the notch where longitudinals or stiffeners pass through the member. Where the width of notch exceeds 15 per cent of the stiffener spacing, the weld factor is to be multiplied by:

$$\frac{0,85 \times \text{Stiffener spacing}}{\text{Length of web plating between notches}}$$

4.10.3 Where direct calculation procedures have been adopted, the weld factors for the 0,1 x overall length at the ends of the members will be considered in relation to the calculated loads.

4.11 Primary and secondary member end connection welds

4.11.1 Welding of end connections of primary members is to be such that the area of welding is not less than the cross-sectional area of the member, and the weld factor is to be not less than 0,34 in tanks or 0,27 elsewhere.

4.11.2 The welding of secondary member end connections is to be not less than as required by *Table 2.4.3 Secondary member end connection welds*. Where two requirements are given the greater is to be complied with.

Table 2.4.3 Secondary member end connection welds

	Connection	Weld area, A_w, in cm^2	Weld factor
(1)	Stiffener welded direct to plating	0,25A_s or 6,5 cm^2 whichever is the greater	0,34
(2)	Bracketless connection of stiffeners or stiffener lapped to bracket or bracket lapped to stiffener:		
	(a) in dry space	$1,2\sqrt{Z}$	0,27
	(b) in tank	$1,4\sqrt{Z}$	0,34
	(c) main frame to tank side bracket in 0,15L_R forward	as (a) or (b)	0,34
(3)	Bracket welded to face of stiffener and bracket connection to plating	-	0,34
(4)	Stiffener to plating for 0,1 x span at ends, or in way of the end bracket if that be greater	-	0,34
Symbols			
A_s = cross section area of the stiffener, in cm^2			
A_w = the area of the weld, in cm^2, and is calculated as total length of weld, in cm, x throat thickness, in cm			
Z = the section modulus, in cm^3, of the stiffener on which the scantlings of the end bracket are based			
Note For maximum and minimum weld fillet sizes, *see Table 10.2.2 Chemical composition of butt welded and forged chain cable*.			

4.11.3 The area of weld, A_w, is to be applied to each arm of the bracket or lapped connection.

4.11.4 Where a longitudinal strength member is cut at a primary support and the continuity of strength is provided by brackets, the area of weld is to be not less than the cross-sectional area of the member.

4.12 Weld connection of strength deck plating to sheerstrake

4.12.1 The weld connection of strength deck plating to sheerstrake is to be by double continuous fillet welding with a weld factor of 0,44. The welding procedure, including joint preparation, is to be specified and the procedure qualified and approved for individual Builders.

4.13 Air and drain holes

4.13.1 Air and drain holes are to be kept clear of the toes of brackets, etc. Openings are to be well rounded with smooth edges. *See also* LR's *Guidance Notes for Structural Details*.

4.14 Notches and scallops

4.14.1 Notches and scallops are to be kept clear of the toes of brackets, etc. Openings are to well rounded with smooth edges.

4.14.2 Scallops are to be of such a size, and in such a position that a satisfactory weld can be made around the ends of openings.

4.15 Watertight collars

4.15.1 Watertight collars are to be fitted, where stiffeners are continuous through watertight or oiltight boundaries. *See also* LR's *Guidance Notes for Structural Details*.

4.16 Lug connections

4.16.1 The area of the weld connecting secondary stiffeners to primary structure in the bottoms of the hulls and cross-deck structure in areas subjected to impact pressures is to be not less than the shear area from the Rules. This area is to be obtained by fitting two lugs or by other equivalent arrangements. Some typical lug connections are shown in *Figure 2.4.4 Typical lug connections* and *Figure 3.1.7 Cut-outs and connections* in Chapter 3.

4.16.2 Lugs or tripping brackets are to be fitted where shell longitudinals are continuous through web frames in way of highly stressed areas of the side shell (e.g. in way of fenders etc).

4.16.3 Lugs or tripping brackets are also to be fitted where continuous secondary stiffeners are greater than half the depth of the primary stiffeners.

4.17 Insert plates

4.17.1 Where thick insert plates are butt welded to thin plates, the edge of the thick plate may require to be tapered. The slope of the taper is generally not to exceed one in three.

4.17.2 The corners of insert plates are to be suitably radiused.

4.18 Doubler plates

4.18.1 Doubler plates are to be avoided in areas where corrosion may be a problem and access for inspection and maintenance is limited.

4.18.2 Where doubler plates are fitted, they are to have well radiused corners and the perimeter is to be continuously welded. Large doubler plates are also to be suitably slot welded, the details of which are to be submitted for consideration.

4.19 Joint preparation

4.19.1 Typical butt joints are shown in LR's *Guidance Notes for Structural Details*.

4.20 Construction tolerances

4.20.1 The minimum requirements for construction tolerances are to be in accordance with *Pt 3, Ch 1, 8 Building tolerances and associated repairs*.

4.21 Riveting of light structure

4.21.1 Where it is proposed to adopt riveted construction, full details of the rivets or similar fastenings, including mechanical test results, are to be indicated on the construction plans submitted for approval or a separate riveting schedule is to be submitted.

4.21.2 Samples may be required of typical riveted joints made by the Builder under representative construction conditions and tested to destruction in the presence of the Surveyor in shear, tension, compression or peel at LR's discretion.

4.21.3 Where riveting strength data sheets have been issued by a recognised Authority, the values quoted in these sheets will normally be accepted for design purposes.

4.21.4 Where two dissimilar metals are to be joined by riveting, precautions are to be taken to eliminate electrolytic corrosion to LR's satisfaction, and where practicable, the arrangements are to be such as to enable the joint to be kept under observation at each survey without undue removal of lining and other items.

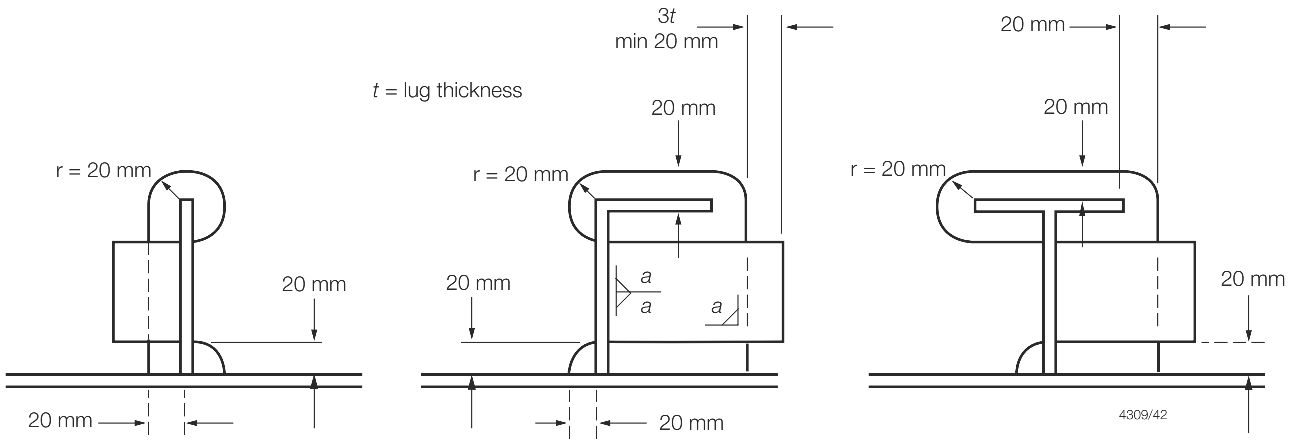


Figure 2.4.4 Typical lug connections

4.21.5 Where a sealing compound is used to obtain an airtight or watertight joint, details are to be submitted of its proposed use and of any tests made or experience gained in its use for similar applications.

4.21.6 Sealing paints or compounds are not to be used with hot driven rivets.

4.22 Chemical bonding of structure

4.22.1 Where chemical bonding of any load-bearing structure is proposed, details of the materials and the processes to be used are to be submitted for approval. These details are to include test results of samples manufactured under LR survey under workshop conditions to verify the strength, ageing effects and moisture resistance.

4.22.2 The adhesive manufacturer's recommendations in respect of the specified jointing system, comprising preparation of the surfaces to be adhered, the adhesive, bonding and curing processes, are to be strictly followed as variation of any step can severely affect the performance of the joint.

4.22.3 Meticulous preparation is essential where the joint is to be made by chemical bonding. The method of producing bonded joints is to be documented so that the process is repeatable after the procedure has been properly established.

4.22.4 Bonded joints are suitable for carrying shear loads, but are not, in general, to be used in tension or where the load causes peeling or other forces tending to open the joint. Loads are to be carried over as large an area as possible.

4.22.5 Bonded joints are to be suitably supported after assembly for the period necessary to allow the optimum bond strength of the adhesive to be to be developed. Entrained air pockets are to be avoided.

4.22.6 The use of adhesive for main structural joints is not to be contemplated unless considerable testing has established its validity, including environmental testing and fatigue testing where considered necessary by LR.

4.23 Triaxial stress considerations

4.23.1 Particular care is to be taken to avoid triaxial stresses which may result from poor joint design. Some recommendations in this respect are contained in LR's *Guidance Notes for Structural Details*.

4.24 Aluminium/Steel transition joints

4.24.1 Provision is made in this Section for explosion bonded composite aluminium/steel transition joints used for connecting aluminium structures to steel plating. Such joints are to be used in accordance with the manufacturer's requirements, *see also Ch 8, 4 Aluminium/steel transition joints* of the Rules for Materials.

4.24.2 Transition joints are to be manufactured by an approved producer in accordance with an approved specification which is to include the maximum temperature allowable at the interface during welding.

4.24.3 The steel material is to comply with the requirements of *Pt 6, Ch 2, 2 Materials* and the aluminium is to be of an appropriate grade complying with the requirements of *Ch 8 Aluminium Alloys* of the Rules for Materials.

4.24.4 Alternative materials which comply with International, National or proprietary specifications may be accepted provided that they give equivalence to the requirements of *Pt 6, Ch 2, 4.24 Aluminium/Steel transition joints 4.24.3* or are approved for a specific application.

4.24.5 Intermediate layers between the aluminium and steel may be used, in which case the material of any such layer is to be specified by the manufacturer and is to be recorded in the approval certificate. Any such intermediate layer is then to be used in all production transition joints.

4.24.6 Bimetallic joints where exposed to seawater or used internally within wet spaces are to be suitably protected to prevent galvanic corrosion.

4.25 Steel/Wood connection

4.25.1 To minimise corrosion of steel when in contact with wood in a damp or marine environment the timber is to be primed and painted in accordance with good practice. Alternatively the surface of the steel in contact with the timber is to be coated with a substantial thickness of a suitable sealant.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull craft of steel construction as defined in *Pt 1, Ch 2, 2 Scope of the Rules*.

1.2 General

1.2.1 The formulae contained within this Chapter are to be used in conjunction with the design loadings from *Pt 5 Design and Load Criteria* to determine the Rule scantling requirements.

1.3 Direct calculations

1.3.1 Where the craft is of unusual design, form or proportions, or where the speed of the craft exceeds 60 knots the scantlings are to be determined by direct calculation.

1.3.2 The requirements of this Chapter may be modified where direct calculation procedures are adopted to analyse the stress distribution in the primary structure.

1.4 Equivalents

1.4.1 Lloyd's Register (hereinafter referred to as 'LR') will consider direct calculations for the derivation of scantlings as an alternative and equivalent to those derived by Rule requirements in accordance with *Pt 3, Ch 1, 3 Equivalents*.

1.5 Symbols and definitions

1.5.1 The symbols used in this Chapter are defined below and in the appropriate Section:

L_R = Rule length of craft, in metres, as defined in *Pt 3, Ch 1, 6 Definitions*

B = moulded breadth of craft, in metres, as defined in *Pt 3, Ch 1, 6 Definitions*

Z = section modulus of stiffening member, in cm^3

I = moment of inertia, in cm^4

A_w = shear area of stiffener web, in cm^2

l = stiffener overall length, in metres

l_e = effective span length, in metres, as defined in *Pt 6, Ch 3, 1.19 Determination of span point*

p = design pressure, in kN/m^2 as given in *Pt 5 Design and Load Criteria*

s = stiffener spacing, in mm

t_p = plating thickness, in mm

β = panel aspect ratio correction factor as defined in *Pt 6, Ch 3, 1.15 Aspect ratio correction*

γ = convex curvature correction factor as defined in *Pt 6, Ch 3, 1.14 Convex curvature correction*

k_s = higher tensile steel factor, as defined in*Pt 6, Ch 2, 2.4 Mechanical properties for design*

σ_s = specified minimum yield strength of the material, in N/mm^2

E = modulus of elasticity, in N/mm^2

1.6 Rounding policy for Rule plating thickness

1.6.1 Where plating thicknesses as determined by the Rules require to be rounded then this should be carried out to the nearest full or half millimetre, with thicknesses 0,75 and 0,25 being rounded up.

1.7 Dimensional tolerance

1.7.1 Dimensional tolerances for materials are to be in accordance with *Ch 8 Aluminium Alloys*of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials), or an acceptable National or International Standard.

1.7.2 The under thickness tolerance acceptable for classification is to be considered as the lower limit of a range of thickness tolerance which could be found in the normal production of a conventional rolling mill manufacturing material, on average, to the nominal thickness.

1.7.3 The Shipowner and Shipbuilder may agree in individual cases whether they wish to specify a more stringent under thickness tolerance than that given in *Pt 6, Ch 3, 1.7 Dimensional tolerance 1.7.2*.

1.7.4 The minus tolerance on sections (except for wide flats) is to be in accordance with a National or International Standard.

1.7.5 The thickness of plates and strip is to be measured at random locations whose distance from an edge is to be at least 25 mm. Local surface depressions resulting from imperfections and ground areas resulting from the elimination of defects may be disregarded provided that they are in accordance with the requirements of a National or International Standard.

1.7.6 The responsibility for maintaining the required tolerances and making the necessary measurements rests with the manufacturer/Builder. Occasional checking by the Surveyor does not absolve the manufacturer/Builder from the responsibility.

1.8 Material properties

1.8.1 The basic grade of steel used in the determination of the Rule scantling requirements is taken as mild steel with the following mechanical properties:

	N/mm^2
Yield strength (minimum)	235
Tensile strength	400 - 490
Modulus of elasticity	200 x 10^3.

1.9 Higher tensile steels

1.9.1 Steels having a yield stress not less than 265 N/mm^2 are regarded as higher tensile steels.

1.9.2 Where higher tensile steels are to be used, due allowance is given in the determination of the Rule requirement for plating thickness and stiffener section modulus, inertia and cross-sectional area by use of the following correction factors:

(a) Plating thickness factor = $\sqrt{k_s}$

(b) Section modulus and cross sectional area factor = k_s

where k_s is as defined in *Pt 6, Ch 3, 1.5 Symbols and definitions 1.5.1*.

1.9.3 The minimum moment of inertia of higher tensile steel stiffening members is to be not less than that required for mild steel stiffening members.

1.9.4 For determination of hull girder section modulus in craft incorporating higher tensile steel materials, *see Pt 6, Ch 6, 2.2 Bending strength 2.2.1*, *Pt 6, Ch 6, 2.2 Bending strength 2.2.2* and *Pt 6, Ch 2, 2.4 Mechanical properties for design 2.4.3*.

1.10 Effective width of attached plating

1.10.1 The effective geometric properties of rolled or built sections are to be calculated directly from the dimensions of the section and associated effective area of attached plating. Where the web of the section is not normal to the actual plating, and the angle exceeds 20^o, the properties of the section are to be determined about an axis parallel to the attached plating.

1.10.2 For stiffening members, the geometric properties of rolled or built sections are to be calculated in association with an effective area of attached load bearing plating of thickness, t_p, in mm and a breadth b_e, in mm. b_e is as defined in *Pt 6, Ch 3, 1.10 Effective width of attached plating 1.10.3* and *Pt 6, Ch 3, 1.10 Effective width of attached plating 1.10.4*.

1.10.3 The effective width of attached plating to secondary members b_e is to be taken as $2t_p\sqrt{E/\sigma_s}$ but not greater than s. σ_s is not to be taken as greater than 235 N/mm^2 for mild steel or 340 N/mm^2 for higher tensile steel. E, s and σ_s are as defined in *Pt 6, Ch 3, 1.5 Symbols and definitions 1.5.1*.

1.10.4 The effective breadth of attached plating to primary support members (girders, transverses, webs, etc.) b_e is to be taken as bf, where b and f are as defined in *Pt 3, Ch 2, 3.2 Geometric properties of sections 3.2.1*.

1.11 Other materials

1.11.1 Special consideration will be given to the use of materials other than steel. Details of the type of material, the specification to which it was manufactured and its mechanical properties are to be submitted for appraisal.

1.12 Aluminium alloys

1.12.1 The use of aluminium alloys in construction is to be in accordance with *Pt 7 Hull Construction in Aluminium*.

1.13 Fibre reinforced plastic (FRP)

1.13.1 The use of FRP in construction is to be in accordance with *Pt 8 Hull Construction in Composite*.

1.14 Convex curvature correction

1.14.1 The thickness of plating as determined by the Rules may be reduced where significant curvature exists between the supporting members. In such cases a plate curvature correction factor may be applied:

γ = plate curvature factor

= 1 - h/s, and is not to be taken as less than 0,7,

h = the distance, in mm, measured perpendicularly from the chord length, s, (i.e. spacing) to the highest point of the curved plating arc between the two supports, *see Figure 3.1.1 Convex curvature*.

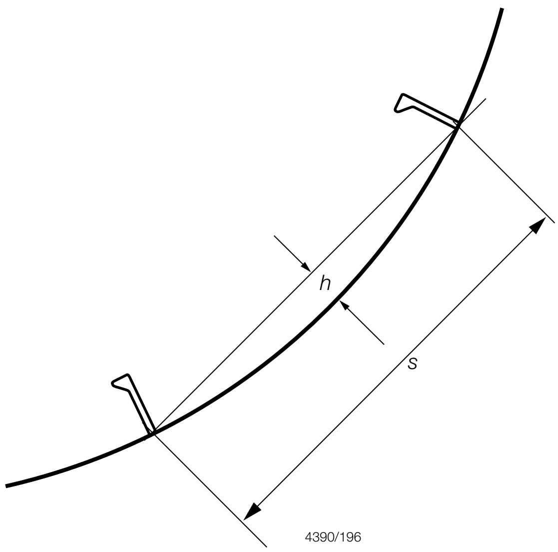


Figure 3.1.1 Convex curvature

1.15 Aspect ratio correction

1.15.1 The thickness of plating as determined by the Rules may be reduced when the panel aspect ratio is taken into consideration. In such cases a panel aspect ratio correction factor may be applied:

β = aspect ratio correction factor

= $A_R(1 - 0{,}25A_R)$ for $A_R \leq 2$

= 1 for $A_R > 2$

A_R = panel aspect ratio

= panel length/panel breadth

1.16 Plating general

1.16.1 The requirements for the thickness of plating, t_p, is, in general, to be in accordance with the following:

$$t_p = 22{,}4 s \gamma\ \beta \sqrt{\frac{p k_s}{f_\sigma 235}} \times 10^{-3} \text{mm}$$

where

f_σ = limiting bending stress coefficient for the plating element under consideration given in *Table 7.3.1 Limiting stress coefficient for local loading* in Chapter 7.

s, γ, β, p, σ_s are as defined in *Pt 6, Ch 3, 1.5 Symbols and definitions 1.5.1*.

k_s is as defined in *Pt 6, Ch 2, 2.4 Mechanical properties for design*.

1.17 Stiffening general

1.17.1 The requirements for section modulus, inertia and web area of stiffening members are, in general, to be in accordance with the following:

(a) Section modulus:

$$Z = \Phi_Z \frac{p s l_e{}^2 k_s}{f_\sigma 235} \quad \text{cm}^3$$

where

Φ_Z = section modulus coefficient dependent on the loading model assumption taken from *Table 3.1.1 Section modulus, inertia and web area coefficients*

f_σ = limiting bending stress coefficient for stiffening member given in *Table 7.3.1 Limiting stress coefficient for local loading* in Chapter 7.

p,*s*,l_e, and σ_s are as defined in *Pt 6, Ch 3, 1.5 Symbols and definitions 1.5.1*.

(b) Inertia:

$$I = F_I f_\delta \frac{p s l_e{}^3}{E} \times 100 \quad \text{cm}^4$$

where

Φ_I = inertia coefficient dependent on the loading model assumption taken from *Table 3.1.1 Section modulus, inertia and web area coefficients*

f_δ = limiting deflection coefficient for stiffener member given in *Table 7.2.1 Limiting deflection ratio* in Chapter 7.

p,*s*,l_e, and *E* are as defined in *Pt 6, Ch 3, 1.5 Symbols and definitions 1.5.1*.

(c) Web area:

$$A_w = \Phi_A \frac{p s l_e k_s}{100 f_\tau \left(\frac{235}{\sqrt{3}}\right)} \quad \text{cm}^2$$

where

Φ_A = web area coefficient dependent on the loading model assumption taken from *Table 3.1.1 Section modulus, inertia and web area coefficients*

f_τ = limiting shear stress coefficient for stiffener member given in *Table 7.3.1 Limiting stress coefficient for local loading* in Chapter 7.

p, *s*and l_e are as defined in *Pt 6, Ch 3, 1.5 Symbols and definitions 1.5.1*.

k_s is defined in *Pt 6, Ch 2, 2.4 Mechanical properties for design*.

1.18 Geometric properties and proportions of stiffener sections

1.18.1 From structural stability and local buckling considerations, the proportions of stiffening members are, in general, to be in accordance with *Table 3.1.2 Stiffener proportions*.

1.19 Determination of span point

1.19.1 The effective span length, l_e, of a stiffening member is generally less than the overall length, l , by an amount which depends on the design of the end connections. The span points, between which the value of l_e is measured, are to be determined as follows:

(a) For rolled or built-up secondary stiffening members:

The span point is to be taken at the point where the depth of the end bracket, measured from the face of the secondary stiffening member, is equal to the depth of the member, *see Figure 3.1.2 Span points*. Where there is no end bracket, the span point is to be measured between primary member webs.

(b) For primary support members:

The span point is to be taken at a point distant, b_e, from the end of the member

$$b_e = b_b\left(1 - \frac{d_w}{d_b}\right)$$

where b_e, b_b, d_w and d_B are as shown in *Figure 3.1.2 Span points*.

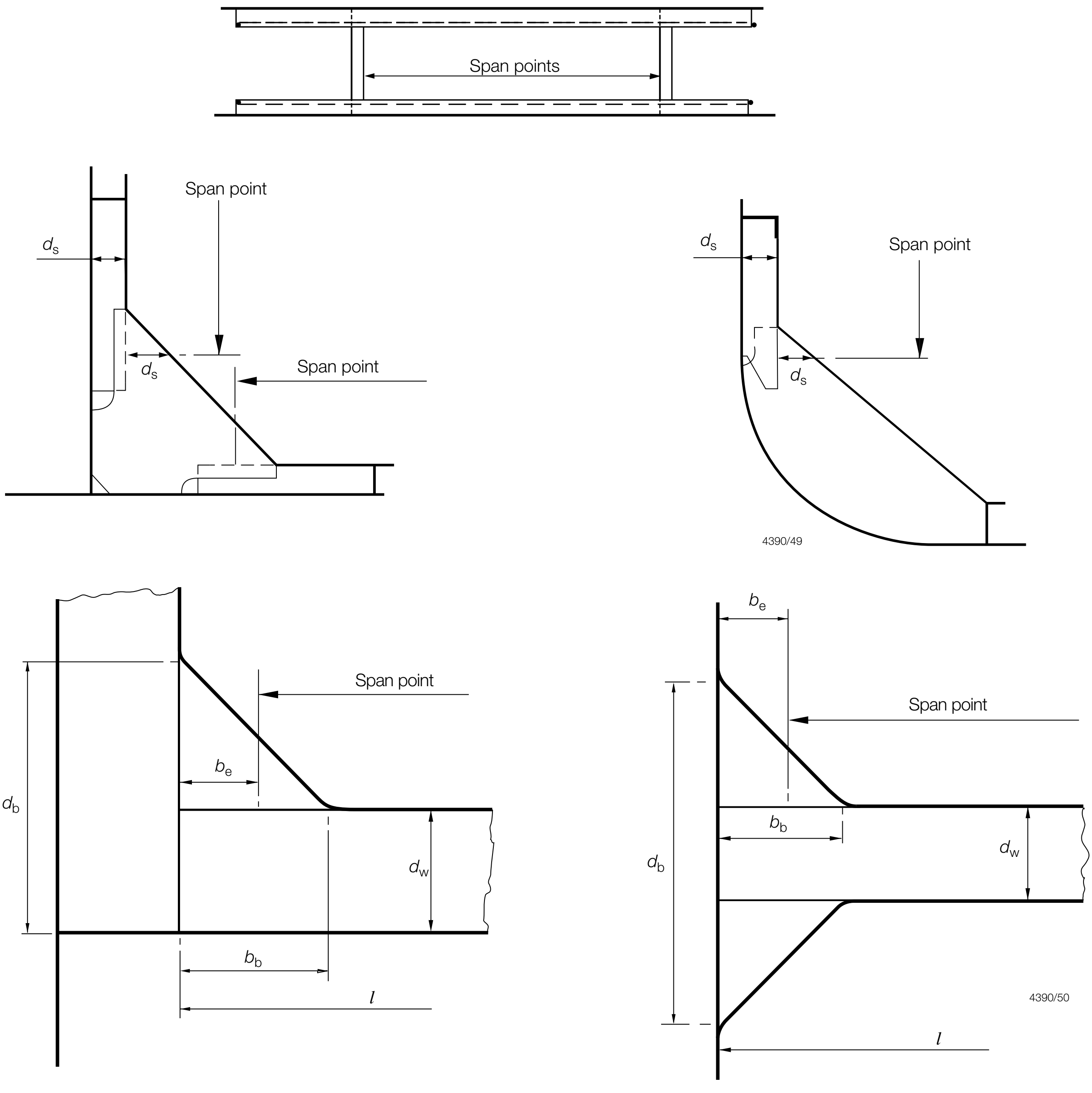


Figure 3.1.2 Span points

1.19.2 Where the stiffening member is inclined to a vertical or horizontal axis and the inclination exceeds 10°, the span is to be measured along the member.

1.19.3 Where the stiffening member is curved then the span is to be taken as the effective chord length between span points.

1.19.4 Where there is a pronounced turn of bilge, chine or the structure is significantly pitched, the span may be measured as in *Figure 3.1.2 Span points*.

1.19.5 It is assumed that the ends of stiffening members are substantially fixed against rotation and displacement. If the arrangement of supporting structure is such that this condition is not achieved, consideration will be given to the effective span to be used for the stiffener.

1.20 Secondary member end connections

1.20.1 Secondary members, that is longitudinals, beams, frames and bulkhead stiffeners forming part of the hull structure, are to be effectively continuous and are to be suitably bracketed at their end connections. Where it is desired to adopt bracketless connections, the proposed arrangements will be individually considered, *see also Pt 6, Ch 2, 4.9 Single sided fillet welding* and *Table 2.4.3 Secondary member end connection welds*.

1.20.2 Where bracketed end connections are fitted in accordance with these requirements, they may be taken into account in determining the effective span of the member.

Table 3.1.1 Section modulus, inertia and web area coefficients

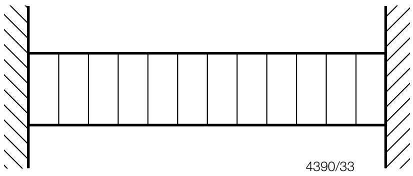
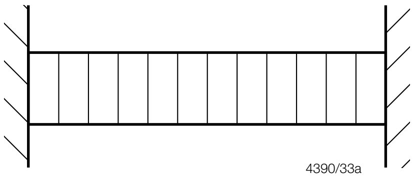
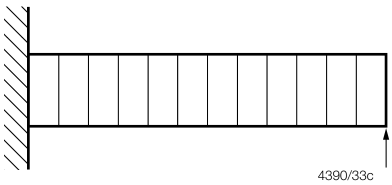
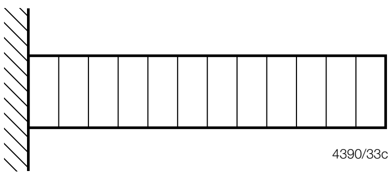
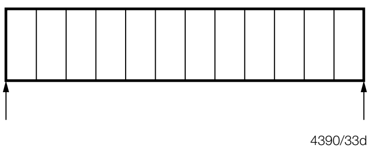
Load model	Position			Position	Web area coefficient Φ_A	Section modulus coefficient Φ_Z	Inertia coefficient Φ_I	Application
	1	2	3					
(a)				1 2 3	1/2 - 1/2	1/12 1/24 1/12	- 1/384 -	Primary and other members where the end fixity is considered encastre
(b)				1 2 3	1/2 - 1/2	1/10 1/10 1/10	- 1/288 -	Local, secondary and other members where the end fixity is considered to be partial
(c)				1 2 3	5/8 - 3/8	1/8 9/128 -	- 1/185 -	Various
(d)				1 2 3	1 - -	1/2 - -	- - 1/8	Various
(e)				1 2 3	1/2 - 1/2	- 1/8 -	- 5/384 -	Hatch covers, glazing and other members where the ends are simply supported

Table 3.1.2 Stiffener proportions

Type of stiffener	Requirement
(1) Flat bar	Minimum web thickness: $t_w = d_w/18 \geq 2{,}5$ mm
(2) Rolled or built sections	(a) Minimum web thickness: $t_w = d_w/65 \geq 2{,}5$ mm (b) Maximum unsupported face plate (or flange) width: $b_f = 16t_f$
Symbols	
t_w = web thickness of stiffener with unstiffened webs, in mm d_w = web depth of stiffener, in mm b_f = face plate (or flange) unsupported width, in mm t_f = face plate (or flange) thickness, in mm	

1.20.3 The scantlings of secondary member end connections are to be in accordance with *Pt 6, Ch 3, 1.21 Scantlings of end brackets*.

1.21 Scantlings of end brackets

1.21.1 Where a longitudinal strength member is cut at a primary support and the continuity of strength is provided by brackets, the scantlings of the brackets are to be such that their section modulus and effective cross-sectional area are not less than those of the member. Care is to be taken to ensure correct alignment of the brackets on each side of the primary member.

1.21.2 In other cases the scantlings of the bracket are to be based on the modulus as follows:

(a) Bracket connecting stiffener to primary member - modulus of the stiffener.
(b) Bracket at the head of a main transverse frame where frame terminates - modulus of the frame.
(c) Brackets connecting lower deck beams or longitudinals to the main frame in the forward $0{,}5L_R$ - modulus of the frame.
(d) Elsewhere - the lesser modulus of the members being connected by the bracket.

1.21.3 The web thickness and face flat area of end brackets are not in general to be less than those of the connecting stiffeners. Additionally, the stiffener proportion requirements of *Pt 6, Ch 3, 1.18 Geometric properties and proportions of stiffener sections* are to be satisfied.

1.21.4 Typical arrangements of stiffener end brackets are shown diagramatically in *Figure 3.1.3 Stiffener end brackets*.

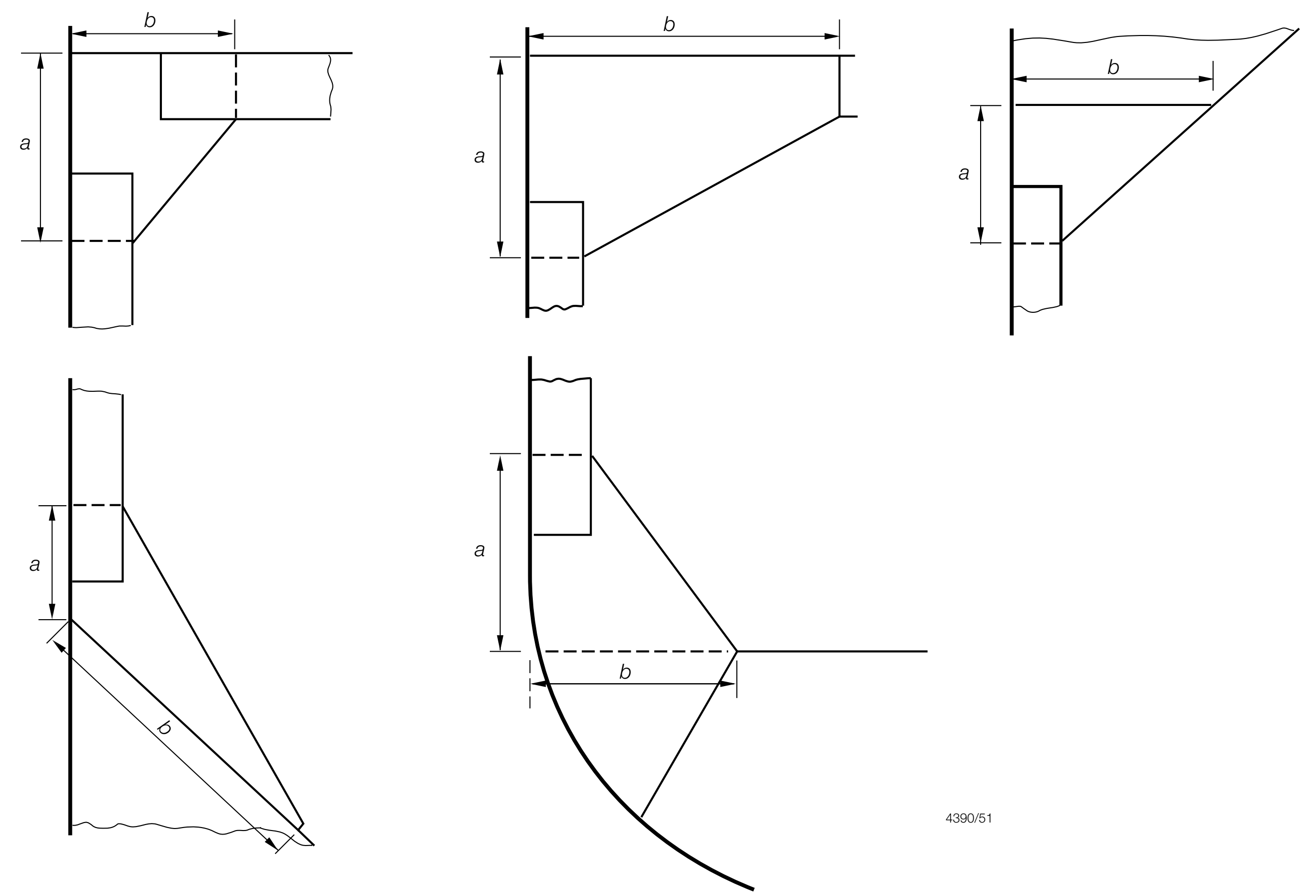


Figure 3.1.3 Stiffener end brackets

1.21.5 The lengths, *a* and *b*, of the arms are to be measured from the plating to the toe of the bracket and are to be such that:

(a) $a + b \geq 2{,}0\, l_b$

(b) $a \geq 0{,}8\, l_b$

(c) $b \geq 0{,}8\, l_b$

where *a* and *b* are the actual lengths of the two arms of the bracket, in mm, measured from the plating to the toe of the bracket.

$$l_b = 90\left(2\sqrt{\frac{Z}{14 + \sqrt{Z}}} - 1\right) \text{ mm}$$

Z = the section modulus of the secondary member, in cm^3

In no case is l_b to be taken as less than twice the web depth of the stiffener on which the bracket scantlings are to be based.

1.21.6 The free edge of the bracket is to be stiffened where any of the following apply:

(a) The section modulus, Z, exceeds 500 cm^3.

(b) The length of free edge exceeds 40 times the bracket thickness.

(c) The bracket is fitted at the lower end of main transverse side framing.

1.21.7 Where a face flat is fitted, its breadth, b_f, is to be not less than:

$$b_f = 40\left(1 + \frac{Z}{1000}\right) \text{ mm}$$

but not less than 50 mm

1.21.8 Where the edge is stiffened by a welded face flat, the cross-sectional area of the face flat is to be not less than:

(a) 0,009 $k_s b_f T_B$ cm^2 for offset edge stiffening.

(b) 0,014 $k_s b_f T_B$ cm^2 for symmetrically placed stiffening.

where

b_f = breadth of face flat, in mm

T_B = the thickness of the bracket, in mm

= k_s is as defined in *Pt 6, Ch 3, 1.5 Symbols and definitions 1.5.1*.

1.21.9 Where the stiffening member is lapped on to the bracket, the length of overlap is to be adequate to provide for the required area of welding. In general, the length of overlap is not to be less than $10\sqrt{Z}$ mm, or the depth of stiffener, whichever is the greater.

1.21.10 Where the free edge of the bracket is hollowed out, it is to be stiffened or increased in size to ensure that the modulus of the bracket through the throat is not less than that of the required straight edged bracket.

1.21.11 The arrangement of the connection between the stiffener and the bracket is to be such that at no point in the connection is the actual modulus reduced to less than that of the stiffener with associated plating.

1.21.12 The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint.

1.22 Primary member end connections

1.22.1 The requirements for section modulus and inertia (if applicable) of primary members are given in the appropriate Chapter. The scantling requirements for primary member end connections in dry spaces and in tanks of all craft types are generally to comply with the requirements of *Pt 6, Ch 3, 1.21 Scantlings of end brackets*, taking Z as the section modulus of the primary member.

1.22.2 Primary members are to be so arranged as to ensure effective continuity of strength, and abrupt changes of depth or section are to be avoided. Where members abut on both sides of a bulkhead, or on other members, arrangements are to be made to ensure that they are in alignment. Primary members in tanks are to form a continuous line of support and wherever possible, a complete ring system.

1.22.3 The members are to have adequate lateral stability and web stiffening and the structure is to be arranged to minimise hard spots and other sources of stress concentration. Openings are to have well rounded corners and smooth edges and are to be located having regard to the stress distribution and buckling strength of the panel.

1.22.4 Primary members are to be provided with adequate end fixity by end brackets or equivalent structure. The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint and effective distribution of the load from the member.

1.22.5 Where the primary member is supported by structure which provides only a low degree of restraint against rotation, the member is generally to be extended beyond the point of support and thereafter tapered and/or scarfed into the adjacent structure over a distance generally not less than two frame spaces.

1.22.6 Where primary members are subject to concentrated loads, particularly if these are out of line with the member web, additional strengthening may be required.

1.22.7 The thickness of the bracket is to be not less than that of the primary member web. The free edge of the bracket is to be stiffened.

1.22.8 Where a deck girder or transverse is connected to a vertical member on the shell or bulkhead, the scantlings of the latter may be required to be increased to provide adequate stiffness to resist rotation of the joint.

1.22.9 Where a member is continued over a point of support, such as a pillar or pillar bulkhead stiffener, the design of the end connection is to be such as to ensure the effective distribution of the load into the support. Proposals to fit brackets of reduced scantlings, or alternative arrangements, will be considered.

1.22.10 Connections between primary members forming a ring system are to minimise stress concentrations at the junctions. Integral brackets are generally to be radiused or well rounded at their toes. The arm length of the bracket, measured from the face of the member, is to be not less than the depth of the smaller member forming the connection.

1.23 Tank boundary penetrations

1.23.1 Where structural members pass through the boundary of a tank, and leakage into the adjacent space could be hazardous or undesirable, full penetration welding is to be adopted for the members for at least 150 mm on each side of the boundary. Alternatively a small scallop of suitable shape may be cut in the member close to the boundary outside the compartment, and carefully welded all round.

1.24 Web stability

1.24.1 Primary members are to be supported by tripping brackets. The tripping brackets supporting asymmetrical sections are to be spaced no more than two secondary frames apart. The tripping brackets supporting symmetrical sections are to be spaced no more than four secondary frames apart.

1.24.2 Tripping brackets are in general required to be fitted at the toes of end brackets and in way of heavy or concentrated loads such as the heels of pillars. *See also* LR's *Guidance Notes for Structural Details*.

1.25 Openings in the web

1.25.1 Where openings are cut in the web, the depth of opening is not to exceed 50 per cent of the web depth, and the opening is to be so located that the edges are not less than 25 per cent of the web depth from the face plate. The length of opening is not to exceed the web depth or 60 per cent of the secondary member spacing, whichever is the greater, and the ends of the openings are to be equidistant from the corners of cut-outs for secondary members. Where larger openings are proposed, the arrangements and compensation required will be specially considered.

1.25.2 Openings are to have smooth edges and well rounded corners.

1.26 Continuity and alignment

1.26.1 The arrangement of material is to be such as will ensure structural continuity. Abrupt changes of shape or section, sharp corners and points of stress concentration are to be avoided.

1.26.2 Where members abut on both sides of a bulkhead or similar structure, care is to be taken to ensure good alignment.

1.26.3 Pillars and pillar bulkheads are to be fitted in the same vertical line wherever possible, and elsewhere arrangements are to be made to transmit the out of line forces satisfactorily. The load at head and heel of pillars is to be effectively distributed and arrangements are to be made to ensure the adequacy and lateral stability of the supporting members.

1.26.4 Continuity is to be maintained where primary members intersect and where the members are of the same depth, a suitable gusset plate is to be fitted, *see Figure 3.1.4 Primary member intersection*.

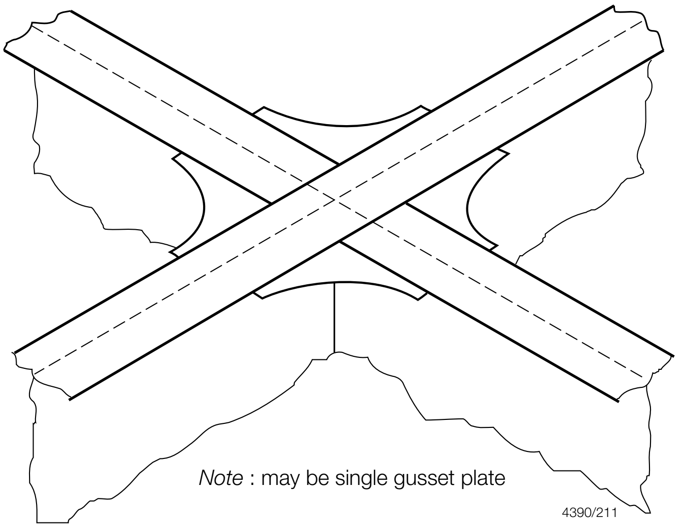


Figure 3.1.4 Primary member intersection

1.26.5 End connections of structural members are to provide adequate end fixity and effective distribution of the load into the supporting structure.

1.26.6 The toes of brackets, etc. are not to land on unstiffened panels of plating. Special care is to be taken to avoid notch effects at the toes of brackets, by making the toe concave or otherwise tapering it off. *See also* LR's *Guidance Notes for Structural Details*.

1.26.7 Particular care is to be paid to the design of the end bracket toes in order to minimise stress concentrations. Sniped face plates which are welded onto the edge of primary member brackets are to be carried well around the radiuses bracket toe and are to incorporate a taper not exceeding one in three. Where sniped face plates are welded adjacent to the edge of primary member brackets, adequate cross sectional area is to be provided through the bracket toe at the end of the snipe. In general, this area measured perpendicular to the face plate, is to be not less than 60 per cent of the full cross-sectional area of the face plate, *see Figure 3.1.5 Bracket toe construction*.

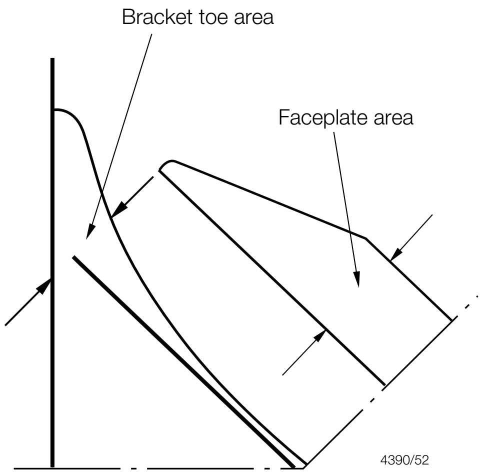


Figure 3.1.5 Bracket toe construction

1.27 Arrangement with offset stiffener

1.27.1 Where the stiffeners of the double bottom floors and transverse bulkheads are unconnected to the secondary members and offset from them (*see Figure 3.1.6 Arrangement with offset stiffener*) the collar arrangement for the secondary members are to satisfy the requirements of *Pt 6, Ch 3, 1.28 Arrangements at intersection of continuous secondary and primary members*. In addition, the fillet welds attaching the lugs to the secondary members are to be based on a weld factor of 0,44 for the throat thickness. To facilitate access for welding the offset stiffeners are to be located 50 mm from the slot edge furthest from the web of the secondary member. The ends of the offset stiffeners are to be suitably tapered and softened.

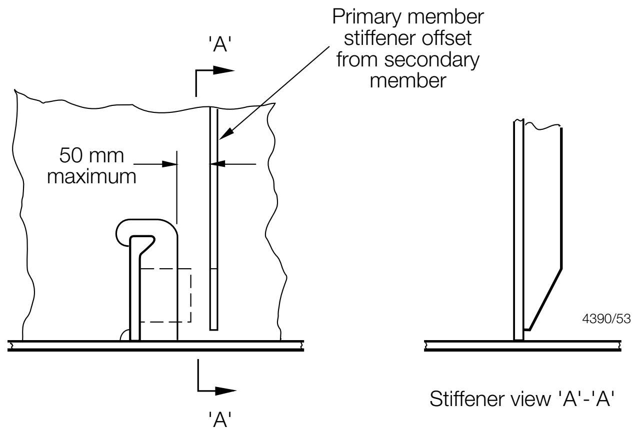


Figure 3.1.6 Arrangement with offset stiffener

1.27.2 Alternative arrangements will be considered on the basis of their ability to transmit load with equivalent effectiveness. Details of the calculations made and testing procedures are to be submitted.

1.28 Arrangements at intersection of continuous secondary and primary members

1.28.1 Cut-outs for the passage of secondary members through the webs of primary members, and the related collaring arrangements, are to be designed to minimise stress concentrations around the perimeter of the opening and in the attached hull envelope or bulkhead plating. The critical shear buckling stress of the panel in which the cut-out is made is to be investigated. Cut-outs for longitudinals will be required to have double lugs in areas of high stress.

1.28.2 The cross-sectional areas of connections are to be determined from the load transmitted through each component in association with its appropriate permissible stress.

1.28.3 The load transmitted through the intersection arrangement is to be determined using the design pressure from*Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft respectively.

1.28.4 Total load, *P*, transmitted to the primary member from the secondary member is to be derived by:

$$P = \frac{s}{1000}\left(S - \frac{s}{2000}\right)p \quad \text{in kN}$$

where

s = secondary stiffener spacing, mm

S = primary stiffener spacing, m

p = design plating pressure, kN/m^2

P = total load, kN

1.28.5 The arrangement of lug/collar/direct connection to the primary web stiffener determines the load apportioned to each component. The effect on each component of the intersection is to be assessed, as appropriate, for shear and direct stress. Where the web stiffener is not connected to the secondary member, the load, *P*, is transmitted through the lug/collar/direct connection.

1.28.6 The breadth of cut-outs is to be as small as practicable, with the top edge suitably radiused. Cut-outs are to have smooth edges, and the corner radii are to be as large as practicable. Where the web depth is greater than 100 mm the corner radii are to be a minimum of 20 per cent of the breadth of the cut-out or 20 mm, whichever is the greater, and for large cut-outs greater than 250 mm deep, the web plate connection to the hull envelope, or bulkhead, should end in a smooth tapered `soft toe'. Recommended shapes of cut-out are shown in *Figure 3.1.7 Cut-outs and connections*, but consideration will be given to other shapes on the basis of maintaining equivalent strength and minimising stress concentration. *See also* LR's *Guidance Notes for Structural Details*.

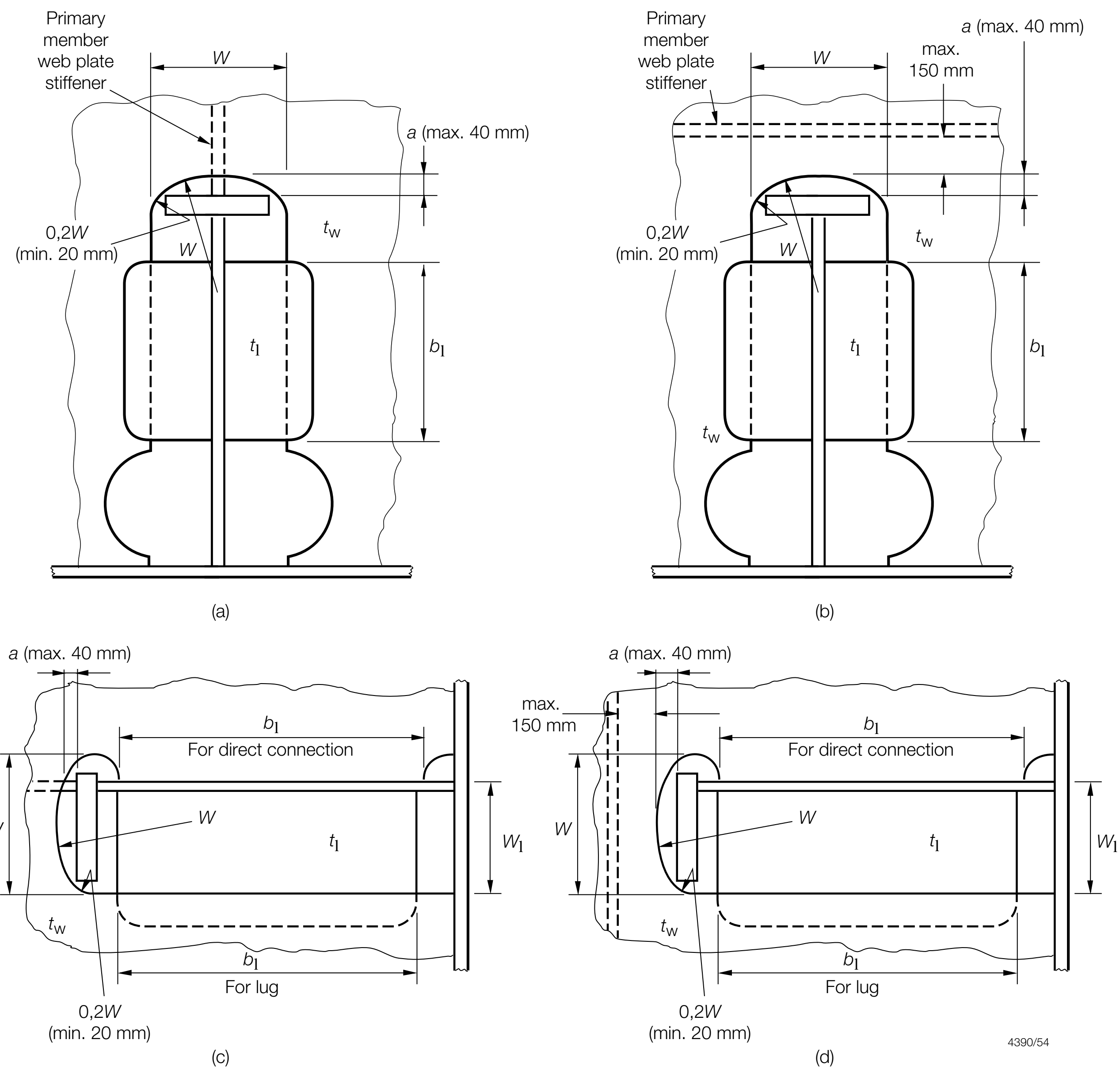


Figure 3.1.7 Cut-outs and connections

1.28.7 Consideration is to be given to the provision of adequate drainage and unimpeded flow of air and water when designing the cut-outs and connection details.

1.28.8 Asymmetrical secondary members are to be connected on the heel side to the primary member web plate. Additional connection by lugs on the opposite side may be required.

1.28.9 Symmetrical secondary members are to be connected by lugs on one or both sides, as necessary.

1.28.10 Where the primary member stiffener is connected to the secondary member it is to be aligned with the web of the secondary member, except where the face plate of the latter is offset and abutted to the web, in which case the stiffener connection is to be lapped.

1.28.11 Fabricated longitudinals having the face plate welded to the underside of the web, leaving the edge of the web exposed, are not recommended for side shell and longitudinal bulkhead longitudinals. Where it is proposed to fit such sections, a

symmetrical arrangement of connection to transverse members is to be incorporated. This can be achieved by fitting backing structure on the opposite side of the transverse web or bulkhead.

1.28.12 Where a bracket is fitted to the primary member web plate in addition to a connected stiffener it is to be arranged on the opposite side to, and in alignment with, the stiffener. The arm length of the bracket is to be not less than the depth of the stiffener, and its cross-sectional area through the throat of the bracket is to be included in the calculation of the area of the primary web stiffener in way of the connection.

1.28.13 Alternative arrangements will be considered on the basis of their ability to transmit load with equivalent effectiveness. Details of the calculations made and testing procedures are to be submitted.

1.29 Openings

1.29.1 Manholes, lightening holes and other cut-outs are to be avoided in way of concentrated loads and areas of high shear. In particular, manholes and similar openings are not to be cut in vertical or horizontal diaphragm plates in narrow cofferdams or in floors and double bottom girders close to their span ends, or below the heels of pillars, unless the stresses in the plating and the panel buckling characteristics have been calculated and found satisfactory.

1.29.2 Manholes, lightening holes and other openings are to be suitably framed and stiffened where necessary.

1.29.3 Air and drain holes, notches and scallops are to be kept at least 200 mm clear of the toes of end brackets and other areas of high stress. Openings are to be well rounded with smooth edges. Closely spaced scallops are not permitted. Widely spaced air or drain holes may be accepted, provided that they are of elliptical shape, or equivalent, to minimise stress concentration and are, in general, cut clear of the weld connection.

1.30 Fittings and attachments, general

1.30.1 The quality of welding and general workmanship of fittings and attachments as given in *Pt 6, Ch 3, 1.31 Bilge keels and ground bars* and *Pt 6, Ch 3, 1.32 Other fittings and attachments* are to be in accordance with *Ch 13 Requirements for Welded Construction* of the Rules for Materials.

1.31 Bilge keels and ground bars

1.31.1 It is recommended that bilge keels are not fitted in the forward $0{,}3L_R$ region on ships intended to navigate in ice conditions.

1.31.2 Bilge keels are to be attached to a continuous ground bar as shown in *Figure 3.1.8 Bilge keel construction*. Butt welds in shell plating, ground bar and bilge keels are to be staggered.

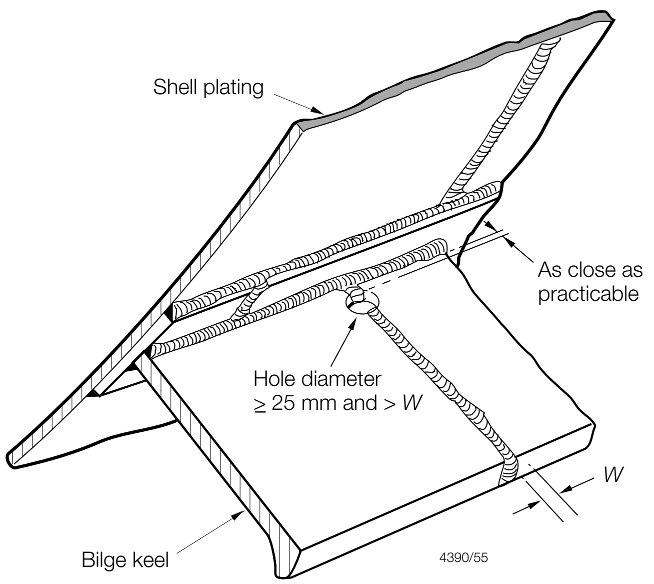


Figure 3.1.8 Bilge keel construction

1.31.3 The thickness of the ground bar is to be not less than the thickness of the bottom shell or 6 mm, whichever is the greater, but need not be taken as greater than 12 mm.

1.31.4 The material class, grade and quality of the ground bar are to be similar to those of the adjacent shell plating.

1.31.5 The ground bar is to be connected to the shell with a continuous fillet weld and the bilge keel to the ground bar with a light continuous fillet weld.

1.31.6 Direct connection between ground bar butt welds and shell plating, and between bilge keel butt welds and ground bar is to be avoided.

1.31.7 The end details of bilge keels and intermittent bilge keels, where adopted, are to be as shown in *Figure 3.1.9 Bilge keel end design*.

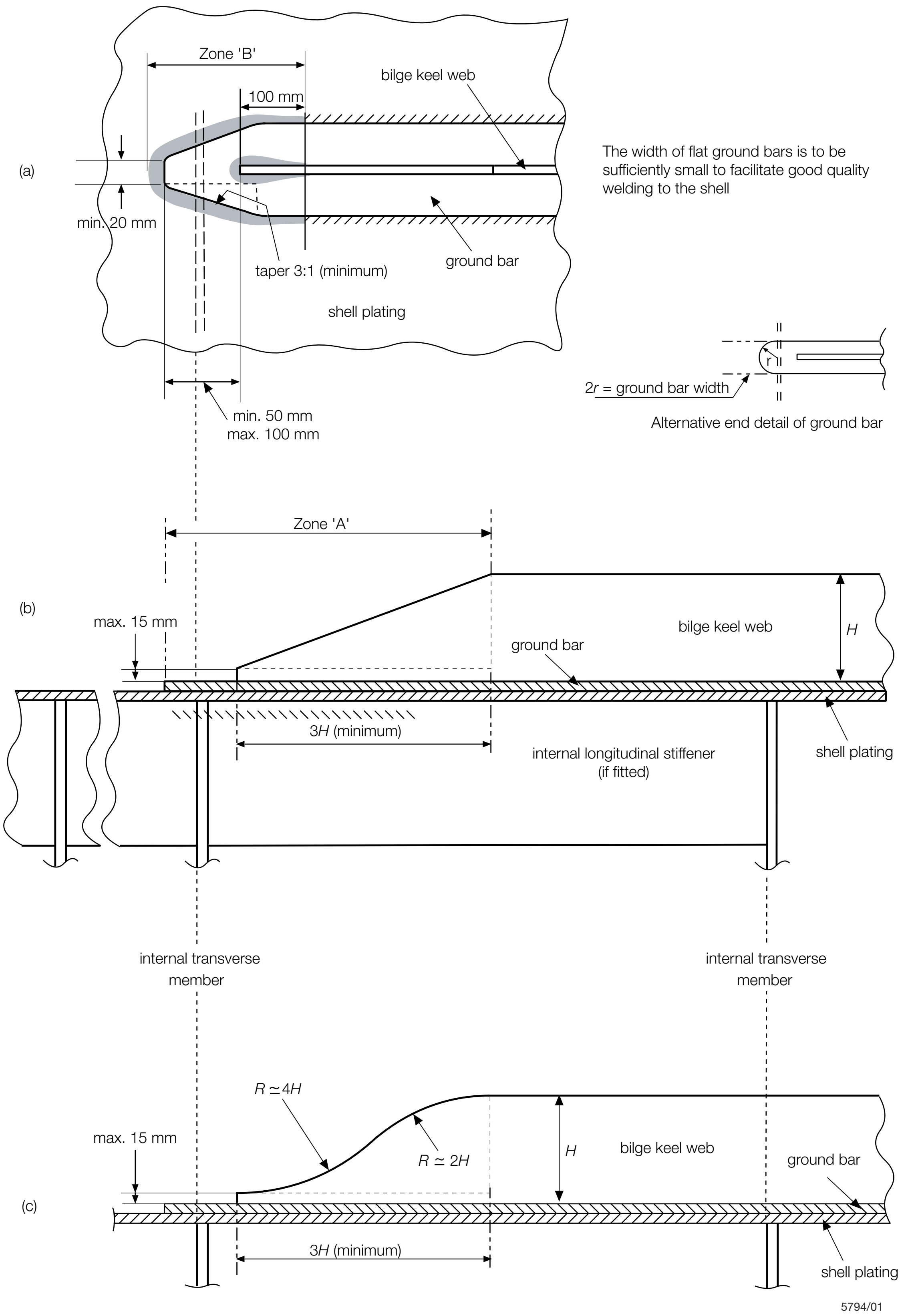


Figure 3.1.9 Bilge keel end design

1.31.8 The ground bar and bilge keel ends are to be tapered or rounded. Where the ends are tapered, the tapers are to be gradual with ratios of at least 3:1, *see Figure 3.1.9 Bilge keel end design* and *Figure 3.1.9 Bilge keel end design*. Where the ends are rounded, details are to be as shown in *Figure 3.1.9 Bilge keel end design*. Cut-outs on the bilge keel web within zone 'A' (*see Figure 3.1.9 Bilge keel end design*) are not permitted.

1.31.9 The end of the bilge keel web is to be between 50 mm and 100 mm from the end of the ground bar, *see Figure 3.1.9 Bilge keel end design*.

1.31.10 An internal transverse support is to be positioned as close as possible to halfway between the end of the bilge keel web and the end of the ground bar, *see Figure 3.1.9 Bilge keel end design*.

1.31.11 Where an internal longitudinal stiffener is fitted in line with the bilge keel web, the longitudinal stiffener is to extend to at least the nearest transverse member outside zone 'A', *see Figure 3.1.9 Bilge keel end design*. In this case, the requirement of *Pt 6, Ch 3, 1.31 Bilge keels and ground bars 1.31.10* does not apply.

1.31.12 For craft over 65 m in length, L_R, holes are to be drilled in the bilge keel butt welds. The size and position of these holes are to be as illustrated in *Figure 3.1.8 Bilge keel construction*. Where the butt weld has been subject to non-destructive examination the stop hole may be omitted.

1.31.13 Bilge keels of a different design from that shown in *Figure 3.1.8 Bilge keel construction* and *Figure 3.1.9 Bilge keel end design* will be specially considered.

1.31.14 Within zone 'B' (*see Figure 3.1.9 Bilge keel end design*), welds at the ends of the ground bar and the bilge plating, and at the ends of the bilge keel web and ground bar, are to have weld factors of 0,44 and 0,34 respectively. These welds are to be ground and to blend smoothly with the base materials.

1.31.15 A plan of the bilge keels is to be submitted for approval of material grades, welded connections and detail design.

1.32 Other fittings and attachments

1.32.1 Gutterway bars at the upper deck are to be so arranged that the effect of main hull stresses on them is minimised.

1.32.2 Minor attachments, such as pipe clips, staging lugs and supports, are generally to be kept clear of toes of end brackets, corners of openings and similar areas of high stress. Where connected to asymmetrical stiffeners, the attachments may be in line with the web provided the fillet weld leg length is clear of the offset face plate or flange edge. Where this cannot be achieved the attachments are to be connected to the web, and in the case of flanged stiffeners they are to be kept at least 25 mm clear of the flange edge. On symmetrical stiffeners, they may be connected to the web or to the centreline of the face plate in line with the web.

1.32.3 Where necessary in the construction of the craft, lifting lugs may be welded to the hull plating but they are not to be slotted through. Where they are subsequently removed, this is to be carried out by mechanical cutting close to the plate surface, and the remaining material and welding ground off. After removal the area is to be carefully examined to ensure freedom from cracks or other defects in the plate surface.

■ *Section 2*
Minimum thickness requirements

2.1 General

2.1.1 The thickness of plating and stiffeners determined from the Rule scantling requirements is in no case to be less than that given in *Table 3.2.1 Minimum thickness requirements* for the craft type.

Table 3.2.1 Minimum thickness requirements

Item	Minimum thickness (mm)		
	Mono-hull	Hydrofoil	Rigid inflatable boat (RIB)
Shell envelope			

Bottom shell plating	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,4\sqrt{L_R}+2,0\right)\geq 3,5\,\omega$	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,4\sqrt{L_R}+2,0\right)\geq 3,5\,\omega$	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,4\sqrt{L_R}+2,0\right)\geq 3,5\,\omega$
Side shell plating	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,38\sqrt{L_R}+1,2\right)\geq 3,0\,\omega$	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,38\sqrt{L_R}+1,2\right)\geq 3,0\,\omega$	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,38\sqrt{L_R}+1,2\right)\geq 3,0\,\omega$
Single bottom structure			
Centre girder web	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,8\sqrt{L_R}+1,0\right)\geq 4,0\,\omega$	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,8\sqrt{L_R}+1,0\right)\geq 4,0\,\omega$	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,8\sqrt{L_R}+1,0\right)\geq 4,0\,\omega$
Floor webs	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,6\sqrt{L_R}+0,8\right)\geq 3,5\,\omega$	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,6\sqrt{L_R}+0,8\right)\geq 3,5\,\omega$	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,6\sqrt{L_R}+0,8\right)\geq 3,5\,\omega$
Side girder webs	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,6\sqrt{L_R}+0,8\right)\geq 3,5\,\omega$	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,6\sqrt{L_R}+0,8\right)\geq 3,5\,\omega$	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,6\sqrt{L_R}+0,8\right)\geq 3,5\,\omega$
Double bottom structure			
Centre girder			
(1) Within 0,4L_R amidships	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,8\sqrt{L_R}+1,0\right)\geq 4,0\,\omega$	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,8\sqrt{L_R}+1,0\right)\geq 4,0\,\omega$	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,8\sqrt{L_R}+1,0\right)\geq 4,0\,\omega$
(2) Outside 0,4L_R amidships	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,7\sqrt{L_R}+1,0\right)\geq 4,0\,\omega$	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,7\sqrt{L_R}+1,0\right)\geq 4,0\,\omega$	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,7\sqrt{L_R}+1,0\right)\geq 4,0\,\omega$
Floors and side girders	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,6\sqrt{L_R}+0,8\right)\geq 3,5\,\omega$	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,6\sqrt{L_R}+0,8\right)\geq 3,5\,\omega$	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,6\sqrt{L_R}+0,8\right)\geq 3,5\,\omega$
Inner bottom plating	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,5\sqrt{L_R}+1,0\right)\geq 2,5\,\omega$	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,5\sqrt{L_R}+1,0\right)\geq 2,5\,\omega$	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,5\sqrt{L_R}+1,0\right)\geq 2,5\,\omega$
Bulkheads			
Watertight bulkhead plating	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,33\sqrt{L_R}+1,0\right)\geq 2,5\,\omega$	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,33\sqrt{L_R}+1,0\right)\geq 2,5\,\omega$	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,33\sqrt{L_R}+1,0\right)\geq 2,5\,\omega$
Deep tank bulkhead plating	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,38\sqrt{L_{\mathrm{R}}}+1,2\right)\geq 3,0\,\omega$	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,38\sqrt{L_{\mathrm{R}}}+1,2\right)\geq 3,0\,\omega$	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,38\sqrt{L_{\mathrm{R}}}+1,2\right)\geq 3,0\,\omega$
Deck plating and stiffeners			
Strength/Main deck plating	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,38\sqrt{L_{\mathrm{R}}}+1,2\right)\geq 3,0\,\omega$	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,38\sqrt{L_{\mathrm{R}}}+1,2\right)\geq 3,0\,\omega$	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,38\sqrt{L_{\mathrm{R}}}+1,2\right)\geq 3,0\,\omega$
Lower deck/Inside deckhouse	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,18\sqrt{L_{\mathrm{R}}}+1,7\right)\geq 2,0\,\omega$	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,18\sqrt{L_{\mathrm{R}}}+1,7\right)\geq 2,0\,\omega$	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,18\sqrt{L_{\mathrm{R}}}+1,7\right)\geq 2,0\,\omega$
Superstructures and deckhouses			
Superstructure side plating	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,3\sqrt{L_{\mathrm{R}}}+1,0\right)\geq 2,0\,\omega$	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,3\sqrt{L_{\mathrm{R}}}+1,0\right)\geq 2,0\,\omega$	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,3\sqrt{L_{\mathrm{R}}}+1,0\right)\geq 2,0\,\omega$
Deckhouse front 1st tier	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,47\sqrt{L_{\mathrm{R}}}+1,5\right)\geq 3,0\,\omega$	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,47\sqrt{L_{\mathrm{R}}}+1,5\right)\geq 3,0\,\omega$	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,47\sqrt{L_{\mathrm{R}}}+1,5\right)\geq 3,0\,\omega$
Deckhouse front upper tiers	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,42\sqrt{L_{\mathrm{R}}}+1,3\right)\geq 3,0\,\omega$	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,42\sqrt{L_{\mathrm{R}}}+1,3\right)\geq 3,0\,\omega$	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,42\sqrt{L_{\mathrm{R}}}+1,3\right)\geq 3,0\,\omega$
Deckhouse aft	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,2\sqrt{L_{\mathrm{R}}}+0,6\right)\geq 2,0\,\omega$	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,2\sqrt{L_{\mathrm{R}}}+0,6\right)\geq 2,0\,\omega$	$\omega\sqrt{k_{\mathrm{ms}}}\left(0,2\sqrt{L_{\mathrm{R}}}+0,6\right)\geq 2,0\,\omega$
Pillars			
Wall thickness of tubular pillars	$\omega\sqrt{k_{\mathrm{ms}}}0,05d_{\mathrm{p}}$	$\omega\sqrt{k_{\mathrm{ms}}}0,05d_{\mathrm{p}}$	$\omega\sqrt{k_{\mathrm{ms}}}0,05d_{\mathrm{p}}$
Wall thickness of rectangular pillars	$\omega\sqrt{k_{\mathrm{ms}}}0,05b_{\mathrm{p}}$	$\omega\sqrt{k_{\mathrm{ms}}}0,05d_{\mathrm{p}}$	$\omega\sqrt{k_{\mathrm{ms}}}0,05d_{\mathrm{p}}$
Symbols			

ω = service type correction factor as determined from *Table 3.2.2 Service type correction factor (ω)*

k_{ms} = 635/(σ_s + σ_u)

σ_u = specified minimum ultimate tensile strength of the material, in N/mm^2

b_p = minimum breadth of cross-section of hollow rectangular pillar, in mm

d_p = outside diameter of tubular pillar, in mm

L_R and σ_s are as defined in *Pt 6, Ch 3, 1.5 Symbols and definitions 1.5.1*

Table 3.2.2 Service type correction factor (ω)

Service type notation	ω
Cargo	1,1
Passenger	1,0
Patrol	1,0
Pilot	1,1
Yacht	1,0
Workboat MFV	1,2

2.1.2 In addition, where plating contributes to the global strength of the craft, the thickness is to be not less than that required to satisfy the global strength requirements detailed in *Pt 6, Ch 6 Hull Girder Strength*.

2.2 Corrosion margin

2.2.1 The minimum thicknesses given in *Table 3.2.1 Minimum thickness requirements* are based on the assumption that there is negligible loss in strength by corrosion. Where this is not the case the minimum thickness will be specially considered.

2.3 Impact consideration

2.3.1 Due consideration is to be given to the scantlings of all structure which may be subject to local impact loadings. Impact testing may be required to be carried out at the discretion of LR to demonstrate the suitability of the proposed scantlings for a particular application.

2.4 Sheathing

2.4.1 Areas of shell and deck which are subject to additional wear by abrasion, e.g. from passenger routes, working areas of fishing vessels, forefoot region etc. are to be suitably protected by local reinforcement or sheathing. This sheathing may be of timber, rubber, steel, additional layers of reinforcement, etc. as appropriate. Details of such sheathing and the method of attachment are to be submitted for consideration.

2.4.2 The attachment of sheathing by mechanical means such as bolting or other methods is not to impair the watertight integrity of the craft. Through bolting of the hull is to be kept to a minimum and avoided where practicable. The design arrangements in way of any through bolting are to be such that damage to the sheathing will not impair the watertight integrity of the hull.

2.5 Operation in ice

2.5.1 The minimum plating thickness of craft intended for operation in ice conditions is to comply with *Pt 6, Ch 5, 7 Strengthening requirements for navigation in ice conditions*.

Section 3
Shell envelope plating

3.1 General

3.1.1 The requirements of this Section are applicable to longitudinally and transversely framed shell envelope plating.

3.1.2 The thickness of the shell envelope plating is in no case to be less than the appropriate minimum requirement given in *Pt 6, Ch 3, 2 Minimum thickness requirements*.

3.2 Plate keel

3.2.1 The breadth, b_k, and thickness, t_k, of the plate keel are not to be taken as less than:

$$b_k = 7,0 L_R + 340 \text{ mm}$$

$$t_k = \sqrt{k_s} 1,35 L_R^{0,45} \text{ mm}$$

where L_R and k_s are as defined in *Pt 6, Ch 3, 1.5 Symbols and definitions 1.5.1*.

3.2.2 In no case is the thickness of the plate keel to be less than that of the adjacent bottom shell plating.

3.2.3 The width and thickness of the plate keel are to be maintained throughout the length of the craft from the transom to a point not less than 25 per cent of the freeboard (measured at the forward perpendicular) above the deepest load waterline on the stem. Thereafter the keel thickness may be reduced to that required by *Pt 6, Ch 3, 3.3 Plate stem 3.3.1* for the stem.

3.2.4 For large or novel craft and for yachts with externally attached ballast keels, the scantlings of the keel will be specially considered.

3.2.5 For bar keels, *see Pt 6, Ch 3, 5.2 Keel 5.2.2*.

3.3 Plate stem

3.3.1 The thickness of plate stems, t_s, is not to be taken as less than:

$$t_s = \sqrt{k_s}\left(0,1 L_R + 3\right) \text{ mm}$$

where

L_R and k_s are as defined in *Pt 6, Ch 3, 1.5 Symbols and definitions 1.5.1*.

3.3.2 In no case is the thickness of the plate stem to be taken as less than the thickness of the adjacent shell plating.

3.3.3 Plate stems are to be supported by horizontal diaphragms, and where the stem radius is large, a centreline stiffener or web may be required. Where this is impracticable due to fabrication access considerations, alternative supporting arrangements will be specially considered.

3.3.4 For large or novel craft the scantlings of the stem will be specially considered.

3.3.5 The breadth of plate stems is to be not less than the width of keel as required by *Pt 6, Ch 3, 3.2 Plate keel 3.2.1*.

3.4 Bottom shell plating

3.4.1 The thickness of the bottom shell plating is to be determined from the general plating equation given in *Pt 6, Ch 3, 1.16 Plating general* using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

3.4.2 For all craft types the minimum thickness requirement for bottom shell plating, *see Figure 3.3.1 Extent of bottom shell*, as detailed in *Pt 6, Ch 3, 2 Minimum thickness requirements*, is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

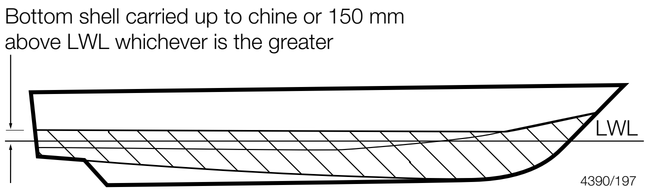


Figure 3.3.1 Extent of bottom shell

3.5 Side shell plating

3.5.1 The thickness of the side shell plating is to be determined from the general plating equation given in *Pt 6, Ch 3, 1.16 Plating general* using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

3.6 Sheerstrake

3.6.1 The sheerstrake is generally to be taken as the side shell, locally reinforced in way of deck/hull connection and fender attachment. The amount of local reinforcement will be dependent upon the arrangement of structure and the proposed service.

3.6.2 The fendering arrangements for all craft types are the responsibility of the designers/Builders and are outside the scope of classification.

3.6.3 Where the pressure or impact loadings that a particular type of craft will experience in service are considered by the Builder, or subsequent Owner, to be not covered by or be greater than those indicated in *Pt 5 Design and Load Criteria* of the Rules, details of the loadings together with the calculations of how these will be satisfactorily distributed into the craft's structure, are to be submitted for consideration with the relevant construction plans.

3.6.4 The arrangements indicated in *Pt 6, Ch 3, 3.6 Sheerstrake 3.6.5*, *Pt 6, Ch 3, 3.6 Sheerstrake 3.6.6*, *Pt 6, Ch 3, 4.18 Structure in way of fenders 4.18.2* and *Pt 6, Ch 3, 4.18 Structure in way of fenders 4.18.3* for pilot and fishing craft are for the guidance of the Builder and subsequent Owners/operators of the craft. Where the intended service for either of these types of craft, or other types of craft which may be subject to loadings resulting from contact with other craft, jetties or similar loading or boarding facilities, is such that the loadings are greater than those that can be satisfactorily distributed into the craft's structure by the arrangements indicated, the strengthening arrangements are to be increased accordingly.

3.6.5 For pilot craft which may be subject to repeated impact loadings from contact with other craft etc. the sheerstrake plating is to be increased locally by not less than 50 per cent of the side shell thickness. The increased thickness is to extend from the bow aft over a distance of $0{,}33L_R$ or 500 mm aft of the point at which the deckline reaches its greatest breadth, whichever is the greater and forward of the quarter and over the transom for a distance of $0{,}075L_R$ or 1,0 m, whichever is the greater. It is in general to extend from the deck edge to below the first longitudinal stiffener, or a vertical distance equivalent to 1/3 the freeboard height whichever is the greater. The additional thickness is then to be tapered out to the side shell thickness in accordance with the Rules.

3.6.6 Fishing craft are in general to have their shell plating scantlings as required to satisfy the Rule loadings, increased by 20 per cent. Additionally the side shell is not to be taken less than as bottom shell thickness, and where there are gallows, gantries, nets, or lines etc. the plating in way is to be further increased locally and/or suitably protected by sheathing or other means.

3.6.7 Individual consideration will be given to lesser scantlings than those required by *Pt 6, Ch 3, 3.6 Sheerstrake 3.6.3*. for fishing craft used for pleasure, light duties, etc.; details of the service are to be submitted.

3.6.8 Where a rounded sheerstrake is adopted the radius is, in general, to be not less than 15 times the thickness.

3.6.9 The sheerstrake thickness is to be increased by 20 per cent at the ends of a bridge superstructure extending out to the craft's side. In the case of a bridge superstructure exceeding $0{,}15L_R$, the side plating at the ends of the superstructure is also to be increased by 25 per cent and tapered gradually into the upper deck sheerstrake.

3.6.10 In general, compensation will not be required for openings in the sheerstrake which are clear of the gunwale or deck openings and whose depth does not exceed 20 per cent of the depth of the sheerstrake. Openings are not to be cut in a rounded gunwale.

3.7 Chines

3.7.1 The chine plate thickness is to be equivalent to the bottom shell thickness required to satisfy the Rule pressure loading, increased by 20 per cent, or 6 mm, whichever is the greater.

3.7.2 Where tube is used in chine construction, the minimum wall thickness is to be not less than the thickness of the bottom shell plating increased by 20 per cent.

3.7.3 Full penetration welding of shell plating in way of chines is always to be maintained.

3.7.4 Chine details are to be such that the continuity of structural strength across the panel is maintained. Details of chines are to be submitted for consideration. *See also* LR's *Guidance Notes for Structural Details*.

3.8 Skegs

3.8.1 The thickness of the skeg plating is to be not less than the thickness of the adjacent bottom shell and additionally is to satisfy the requirements for solepieces given in *Pt 3, Ch 3, 3 Sternframes and appendages*.

3.9 Transom

3.9.1 The thickness of the stern or transom is to be not less than that required for the side or bottom shell as appropriate. Where water jet or sterndrive units are fitted, the scantlings of the plating in way of the nozzles and connections will be specially considered.

3.10 Fin and tuck

3.10.1 The thickness of the plating is to be increased locally in way of the fin and tuck areas of yachts which have either internal fixed ballast or external attached ballast keels.

3.10.2 The plating thickness is to be not less than 1,25 times the thickness of the adjacent shell plating but need not be greater than the plate keel thickness as required by *Pt 6, Ch 3, 3.2 Plate keel*.

3.11 Shell openings

3.11.1 Sea-inlets, or other openings, are to have well rounded corners and, so far as is practicable, are to be kept clear of the bilge radius, chine or radiused sheerstrake. Arrangements are to be made to maintain the strength in way of the openings.

3.11.2 Openings on or near the bilge radius may be accepted provided that they are of elliptical shape, or equivalent, to minimize stress concentrations and are, in general, to be cut clear of weld connections.

3.12 Sea inlet boxes

3.12.1 The thickness of the sea inlet box plating is to be 2 mm thicker than the adjacent shell plating, or 6 mm, whichever is the greater.

3.13 Local reinforcement/Insert plates

3.13.1 The thickness of the shell envelope plating determined in accordance with *Pt 6, Ch 3, 3.4 Bottom shell plating* and *Pt 6, Ch 3, 3.5 Side shell plating* is to be increased locally, by generally not less than 50 per cent in way of sternframe, propeller brackets, rudder horn, stabilisers, hawse pipes, anchor recess, etc. Details of such reinforcement are to be submitted for approval.

3.13.2 Insert plates are to extend outside the line of adjacent supporting structure and then be tapered over a distance of not less than three times the difference in thickness, *see also Pt 6, Ch 2, 4.21 Riveting of light structure*.

3.14 Appendages

3.14.1 The scantlings of appendages will be subject to special consideration on the basis of the Rules and the design loadings anticipated, but are, in no case, to be taken as less than that of the surrounding structure.

3.15 Fender attachment

3.15.1 Wood belting and fenders are to be bolted to lugs welded to a ground bar attached to the shell and not through-bolted to the shell plating.

3.16 Novel features

3.16.1 Where the Rules do not specifically define the requirements for novel features then the scantlings and arrangements are to be determined by direct calculation. Such calculations are be carried out on the basis of the Rules or recognised standards. Details are to be submitted for consideration.

■ *Section 4*
Shell envelope framing

4.1 General

4.1.1 The requirements in this Section apply to longitudinally and transversely framed shell envelopes.

4.1.2 For each stiffening member an assumed load model is stated. Where the proposed stiffener arrangement differs from that assumed, consideration will be given to an alternative load model.

4.1.3 The geometric properties of stiffener sections are to be in accordance with *Pt 6, Ch 3, 1.18 Geometric properties and proportions of stiffener sections*

4.2 Bottom longitudinal stiffeners

4.2.1 Bottom longitudinal stiffeners are to be supported by bottom transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.2.2 Bottom longitudinals are to be continuous through the supporting structures.

4.2.3 Where it is impracticable to comply with the requirements of *Pt 6, Ch 3, 4.2 Bottom longitudinal stiffeners 4.2.2*, or where it is proposed to terminate the bottom longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.2.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 6, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3 Hull envelope design criteria* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (b).

4.3 Bottom longitudinal primary stiffeners

4.3.1 Bottom longitudinal primary stiffeners are to be supported by bottom deep transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 6 m apart.

4.3.2 Bottom longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

4.3.3 Where it is impracticable to comply with the requirements of *Pt 6, Ch 3, 4.3 Bottom longitudinal primary stiffeners 4.3.2*, or where it is proposed to terminate the stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be `soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.3.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 6, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (a).

4.4 Bottom transverse stiffeners

4.4.1 Bottom transverse stiffeners are defined as local stiffening members which support the bottom shell, and which may be continuous or intercostal.

4.4.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 6, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures*

for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (b).

4.5 Bottom transverse frames

4.5.1 Bottom transverse frames are defined as stiffening members which support the bottom shell. They are to be effectively continuous and bracketed at their end connections to side frames and bottom floors as appropriate.

4.5.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 6, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (a).

4.6 Bottom transverse web frames

4.6.1 Bottom transverse web frames are defined as primary stiffening members which support bottom shell longitudinals. They are to be continuous and substantially bracketed at their end connections to side web frames and bottom floors.

4.6.2 Where it is impracticable to comply with the requirements of *Pt 6, Ch 3, 4.6 Bottom transverse web frames 4.6.1*, or where it is proposed to terminate the bottom transverse web frames in way of longitudinal primary girders, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be `soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.6.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 6, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (a).

4.7 Side longitudinal stiffeners

4.7.1 The side longitudinal stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.7.2 Side longitudinals are to be continuous through the supporting structures.

4.7.3 Where it is impracticable to comply with the requirements of *Pt 6, Ch 3, 4.7 Side longitudinal stiffeners 4.7.2*, or where it is proposed to terminate the side longitudinal in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.7.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 6, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (b).

4.8 Side longitudinal primary stiffeners

4.8.1 Side longitudinal primary stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 6 m apart.

4.8.2 Side longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

4.8.3 Where it is impracticable to comply with the requirements of *Pt 6, Ch 3, 4.8 Side longitudinal primary stiffeners 4.8.2*, or where it is proposed to terminate the side longitudinal in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be `soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.8.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 6, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (a).

4.9 Side transverse stiffeners

4.9.1 Side transverse stiffeners are defined as local stiffening members supporting the side shell and may be continuous or intercostal.

4.9.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 6, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (b).

4.10 Side transverse frames

4.10.1 Side transverse frames are defined as stiffening members supporting the side shell and spanning continuously between bottom floors/frames and decks. They are to be effectively constrained against rotation at their end connections.

4.10.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 6, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (a).

4.11 Side transverse web frames

4.11.1 Side transverse web frames are defined as primary stiffening members which support side shell longitudinals. They are to be continuous and substantially bracketed at their head and heel connections to deck transverses and bottom web frames respectively.

4.11.2 Where it is impracticable to comply with the requirements of *Pt 6, Ch 3, 4.11 Side transverse web frames 4.11.1*, or where it is proposed to terminate the web frames in way of side longitudinal primary stiffeners, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be `soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.11.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 6, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (a).

4.12 Grouped frames

4.12.1 For the purposes of satisfying Rule scantling requirements, frames may, subject to agreement by LR, be grouped. The number of frames in any group shall not in general exceed five. The summation of the section modulii and inertia for the group of frames is not to be less than the summation of the Rule requirement for the individual framing members. In addition, in no case is the proposed scantling of an individual framing member within the group to be less than ninety per cent of the Rule value for that member.

4.13 Grillage structures

4.13.1 For complex girder systems, a complete structural analysis using numerical methods may have to be performed to demonstrate that the stress levels are acceptable when subjected to the most severe and realistic combination of loading conditions intended.

4.13.2 General or special purpose computer programs or any other analytical techniques may be used provided that the effects of bending, shear, axial and torsion are properly accounted for and the theory and idealisation used can be justified.

4.13.3 In general, grillages consisting of slender girders may be idealised as frames based on beam theory provided proper account of the variations of geometric properties is taken. For cases where such an assumption is not applicable, finite element analysis or equivalent methods may have to be used.

4.14 Combined framing systems

4.14.1 Where longitudinal and transverse primary stiffeners form grillage structures the scantlings may be derived in accordance with *Pt 6, Ch 3, 4.13 Grillage structures*.

4.15 Floating framing systems

4.15.1 Floating framing systems, where proposed, will be subject to special consideration.

4.16 Frame struts

4.16.1 Where struts are fitted to side shell transverse web frames or longitudinal primary stiffeners to carry axial loads, the strut cross-sectional area is to be derived as for pillars in *Pt 6, Ch 3, 10 Pillars and pillar bulkheads*. If fitted at the stiffener half span point, the stiffener section modulus may be taken as half the modulus derived above.

4.16.2 Design of end connections is to be such that the area of the welding is to be not less than the minimum cross-sectional area of the strut derived in *Pt 6, Ch 3, 4.16 Frame struts 4.16.1*. To achieve this full penetration welding may be required. The weld connections between the face flats and webs of the pillar supporting structure are to be welded using double continuous welding of an equivalent area to that derived by *Pt 6, Ch 3, 4.16 Frame struts 4.16.1*.

4.17 Arrangements and details

4.17.1 The arrangement of the connection between the stiffener and the bracket is to be such that at no point in the connection are the section modulus and inertia reduced to less than that of the stiffener with associated plating.

4.17.2 The web stability, openings in the web and continuity and alignment are to be in accordance with *Pt 6, Ch 3, 1.24 Web stability*, *Pt 6, Ch 3, 1.25 Openings in the web* and *Pt 6, Ch 3, 1.26 Continuity and alignment*, respectively.

4.17.3 Secondary and primary end connections and arrangements at intersection of continuous secondary and primary members are to be in accordance with *Pt 6, Ch 3, 1.20 Secondary member end connections*, *Pt 6, Ch 3, 1.22 Primary member end connections* and *Pt 6, Ch 3, 1.28 Arrangements at intersection of continuous secondary and primary members*, respectively.

4.17.4 Stiffeners in slamming areas are to be lugged or bracketed.

4.18 Structure in way of fenders

4.18.1 For **craft**, including pilot boats and fishing vessels, which may be subject to repeated impact loadings from contact with other craft whilst in service, due consideration is to be given to increasing the scantlings of stiffening members in way of fenders. Details of anticipated loadings and calculations for the required increased scantlings are to be submitted, *see also Pt 6, Ch 3, 3.6 Sheerstrake 3.6.3* and *Pt 6, Ch 3, 3.6 Sheerstrake 3.6.4*.

4.18.2 **Pilot craft** are to be fitted with large knees in way of the sheerstrake in areas as indicated in *Pt 6, Ch 3, 3.6 Sheerstrake*. The knees are to be aligned between the transverse frames and the deck beams. In the case of longitudinally framed craft, intermediate knees are to be fitted with a spacing in general not greater than 500 mm. Where such intermediate brackets are fitted they are to terminate on a side longitudinal with a section modulus of, in general, twice that of the Rule longitudinal for the web frame spacing, and a deck longitudinal. The side longitudinal is to be positioned below any fendering to carry the heel of the knee. Consideration will given to the termination of such brackets by use of a `soft-toe' in way of the deck. The thickness of the webs for these knees is to be twice that required by *Pt 6, Ch 3, 1.21 Scantlings of end brackets*.

4.18.3 **Fishing craft** engaged in pair trawling and other modes of fishing, and which may be subject to repeated impact loading from contact with the other craft are to have additional stiffening fitted in way of the impact areas. This may be in the form of large knees, intermediate knees, substantial fendering/rubbing strakes.

4.19 Novel features

4.19.1 The scantlings are to be determined by direct calculation where the shell framing is of unusual design, form or proportions.

■ *Section 5*
Single bottom structure and appendages

5.1 General

5.1.1 The requirements of this Section provide for single bottom construction in association with transverse and longitudinal framing systems.

5.1.2 All girders are to extend as far forward and aft as practicable and care is to be taken to avoid any abrupt discontinuity. Where girders are cut at bulkheads, their longitudinal strength is to be maintained.

5.1.3 Particular care is to be taken to ensure that the continuity of structural strength in way of the intersection of transverse floors and longitudinal girders is maintained. The face flats of such stiffening members are to be effectively connected.

5.1.4 The single bottom structure in way of the keel and girders is to be sufficient to withstand the forces imposed by dry-docking the craft.

5.1.5 The scantlings of the single bottom structure are to comply with the appropriate minimum requirements given in *Pt 6, Ch 3, 2 Minimum thickness requirements*.

5.2 Keel

5.2.1 The breadth, and thickness of plate keels are to comply with the requirements of *Pt 6, Ch 3, 3.2 Plate keel*.

5.2.2 The cross-sectional area, A_{k}, and thickness, t_{k}, of bar keels are not, in general, be taken as less than:

$$A_{\text{k}} = k_{\text{s}}\left(L_{\text{R}} + 1\right) \text{cm}^2$$

$$t_{\text{k}} = \sqrt{k_{\text{s}}}\ \left(0,5L_{\text{R}} + 6\right) \text{mm}$$

where L_{R} and k_{s} are as defined in *Pt 6, Ch 3, 1.5 Symbols and definitions 1.5.1*.

5.3 Centre girder

5.3.1 A centreline girder is, in general, to be fitted throughout the length of the hull in association with transverse frames, transverses supporting longitudinals or where the breadth of floors at the upper edge is greater than 1,5 m.

5.3.2 Centreline girders are to be formed of intercostal or continuous plate webs with a face flat welded to the upper edge. In all cases the face flat is to be continuous. Where girder webs are intercostal, additional bracketing and local reinforcement will be required to maintain the continuity of structural strength.

5.3.3 The web depth of the centre girder is in general to be equal to the depth of the floors at the centreline as specified in *Pt 6, Ch 3, 5.5 Floors general 5.5.3*.

5.3.4 The web thickness, t_{w}, is to be taken not less than:

$$t_w = \sqrt{k_{\text{s}}}\left(\sqrt{L_{\text{R}}} + 1\right) \text{mm}$$

where L_{R} and k_{s} are as defined in *Pt 6, Ch 3, 1.5 Symbols and definitions 1.5.1*.

5.3.5 The geometric properties of the centre girder are to be in accordance with *Pt 6, Ch 3, 1.18 Geometric properties and proportions of stiffener sections*.

5.3.6 The face flat area of the centre girder, A_{f}, is to be not less than:

$$A_{\text{f}} = 0,3L_{\text{R}}k_{\text{s}} \text{cm}^2$$

where L_{R} and k_{s} are as defined in *Pt 6, Ch 3, 1.5 Symbols and definitions 1.5.1*.

5.3.7 The face flat area of the centre girder outside 0,5L_{R} may be 80 per cent of the value given in *Pt 6, Ch 3, 5.3 Centre girder 5.3.6*.

5.3.8 The face flat thickness is to be not less than the thickness of the web.

5.3.9 The ratio of the width to thickness of the face flat is to be not less than 8 but is not to exceed 16.

5.3.10 Additionally, the requirements of *Pt 6, Ch 3, 4.3 Bottom longitudinal primary stiffeners* for bottom longitudinal primary stiffeners are to be complied with.

5.4 Side girders

5.4.1 Where the floor breadth at the upper edge exceeds 6,0 m side girders are to be fitted at each side of the centre girder such that the spacing between the side and centre girders or between the side girders themselves is not greater than 3 metres. Side girders where fitted are to extend as far forward and aft as practicable and are, in general, to terminate in way of bulkheads, deep floors or other primary transverse structure.

5.4.2 The web thickness of side girders is to be taken as not less than:

$$t_w = \sqrt{(k_s L_R)} \text{ mm}$$

where L_R and k_s are as defined in *Pt 6, Ch 3, 1.5 Symbols and definitions 1.5.1*.

5.4.3 The face flat area and thickness of side girders are to comply with the requirements for plate floors as defined in *Pt 6, Ch 3, 5.5 Floors general 5.5.6* and *Pt 6, Ch 3, 5.5 Floors general 5.5.7*.

5.4.4 Watertight side girders, and side girders forming the boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads and deeptanks as detailed in *Pt 6, Ch 3, 7.3 Watertight bulkhead stiffening* and *Pt 6, Ch 3, 7.5 Deep tank stiffening* respectively.

5.4.5 In the engineroom, additional side girders are generally to be fitted in way of main machinery seatings. Where fitted, they are to be integrated into the structure of the craft and extended forward and aft as far as practicable.

5.4.6 Additionally, the requirements of *Pt 6, Ch 3, 4.3 Bottom longitudinal primary stiffeners* for bottom longitudinal primary stiffeners are to be complied with.

5.5 Floors general

5.5.1 In transversely framed craft, plate floors are generally to be fitted at each frame.

5.5.2 In longitudinally framed craft, plate floors are to be fitted at every transverse web frame and generally at a spacing not exceeding 2 m. Additional transverse floors or webs are in general to be fitted at half web-frame spacing in way of engine seatings and thrust bearings, pillars, skegs, ballast/bilge keels and the bottom of the craft forward.

5.5.3 The overall depth, d_f, of plate floors at the centreline is not to be taken as less than:

when B < 10 m	$d_f = 40(B + 0{,}85D)$ mm
when B ≥ 10 m	$d_f = 40(1{,}5B + 0{,}85D) - 200$ mm

where D is defined in *Pt 3, Ch 1, 6.2 Principal particulars 6.2.6*.

B is as defined in *Pt 6, Ch 3, 1.5 Symbols and definitions 1.5.1*.

5.5.4 The web thickness, t_w, of plate floors, is to be in accordance with *Pt 6, Ch 3, 1.18 Geometric properties and proportions of stiffener sections* and is to be taken as not less than:

$$t_w = \sqrt{k_s}\left(\frac{3{,}4d_f}{1000} + 2{,}25\right)\left(\frac{s}{1000} + 0{,}5\right) \text{ mm}$$

where

d_f is to be determined from *Pt 6, Ch 3, 5.5 Floors general 5.5.3*

k_s and s are as defined in *Pt 6, Ch 3, 1.5 Symbols and definitions 1.5.1*.

5.5.5 If the side frames of the craft are attached to the floors by brackets, the depth of floor may be reduced by 15 per cent and the floor thickness determined using the reduced depth. The brackets are to be flanged and have the same thickness as the floors, and their arm lengths clear of the frame are to be the same as the reduced floor depth given above.

5.5.6 The face flat area of floors, A_f, is not to be taken as less than:

$$A_f = k_s 0{,}15 L_R \text{ cm}^2$$

where

k_s and L_R are defined in *Pt 6, Ch 3, 1.5 Symbols and definitions 1.5.1*.

5.5.7 The face flat thickness is to be not less than the thickness of the web and the ratio of the web to the thickness of the face flat is to be not less than 8 but is not to exceed 16.

5.5.8 Additionally the requirements of *Pt 6, Ch 3, 4.6 Bottom transverse web frames* for bottom transverse web frames are to be complied with.

5.5.9 Floors are generally to be continuous from side to side.

5.5.10 The tops of floors, in general, may be level from side to side. However, in craft having considerable rise of floor the depth of the floor plate may require to be increased to maintain the required section modulus.

5.5.11 The floors in the aft peak are to extend over and provide effective support to the sterntube(s) where applicable.

5.5.12 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deeptanks as detailed in *Pt 6, Ch 3, 7.3 Watertight bulkhead stiffening* and *Pt 6, Ch 3, 7.5 Deep tank stiffening*.

5.6 Floors in machinery spaces

5.6.1 The thickness, t_w, of the floors in machinery spaces is to be 1 mm greater than that required by *Pt 6, Ch 3, 5.5 Floors general 5.5.4*.

5.6.2 The depth and section modulus of floors anywhere between engine or gearbox girders is to be not less than that required to maintain continuity of structural integrity or 50 per cent of the depth given in *Pt 6, Ch 3, 5.5 Floors general 5.5.3*. The face flat area and web thickness for such reduced floor heights are to be increased appropriately in order to maintain continuity of structural strength, *see also Pt 6, Ch 3, 4.12 Grouped frames*.

5.7 Machinery seatings

5.7.1 The general requirements for machinery seatings are given in *Pt 3, Ch 2, 6.9 Machinery seatings*, *see also Pt 9, Ch 1, 5 Securing of machinery*.

5.7.2 Engine holding-down bolts are to be arranged as near as practicable to floors and longitudinal girders. When this cannot be achieved, bracket floors are to be fitted.

5.7.3 Welding in way of machinery seatings is to be double continuous and/or full penetration where appropriate.

5.8 Drainholes in bottom structure

5.8.1 Sufficient limber holes are to be cut in the internal bottom structure to allow for the drainage of water from all parts of the bilge to the pump suctions.

5.8.2 Particular care is to be given to the positioning of limber holes to ensure adequate drainage and to avoid stress concentrations.

5.8.3 Suitable arrangements are to be made to provide free passage of air from all parts of tanks to the air pipes.

5.9 Rudder horns

5.9.1 The shell plating thickness in way of the rudder horn is to be increased locally, by generally not less than 50 per cent but need not to be taken as greater than the keel thickness required by *Pt 6, Ch 3, 3.2 Plate keel*.

5.9.2 The scantlings of the rudder horn are to be such that the section modulus against transverse bending, Z_r, at any horizontal section XX (*see Figure 3.5.1 Rudder horn*) is not less than:

$$Z_r = 1,5 k_s R_A K_V (V+3)^2 \sqrt{a^2 + 0,5 b^2}\ \text{cm}^3$$

where

R_A = total rudder area, in m^2

V = maximum speed in the fully loaded condition, in knots

K_V = 1,0 for displacement craft with $V/\sqrt{L_{WL}} < 3,0$

= $(1,12 - 0,005\,V)^3$ for planing and semi-planing craft with $V/\sqrt{L_{WL}} \geq 3,0$

a, b = dimensions, in metres, as given in *Figure 3.5.1 Rudder horn*

L_{WL} = is as defined in *Pt 3, Ch 1, 6.2 Principal particulars 6.2.5*

5.9.3 Rudder horns are to be effectively integrated into the adjacent structure and their design is to be such as to facilitate this.

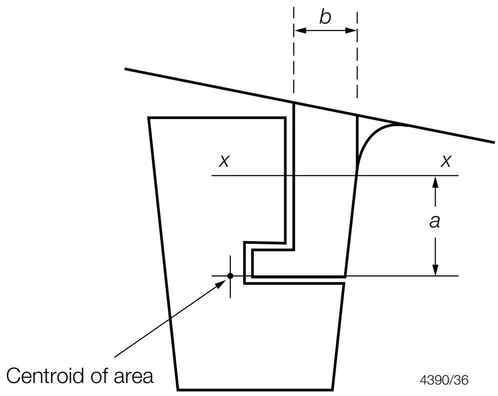


Figure 3.5.1 Rudder horn

5.10 Sternframes

5.10.1 The scantlings of fabricated and forged/solid sternframes are to comply with the requirements of *Pt 3, Ch 3, 3 Sternframes and appendages* modified for appropriate grade of steel in accordance with *Pt 3, Ch 3, 1.2 General*.

5.11 Skeg construction

5.11.1 Skegs are to be effectively integrated into the adjacent structure and their design is to be such as to facilitate this.

5.11.2 The scantlings and arrangements for skegs (solepieces) are to be in accordance with *Pt 3, Ch 3, 3.14 Solepieces*.

5.11.3 The scantlings of skegs are to be sufficient to withstand any docking forces that they may be subjected to.

5.12 Forefoot and stem

5.12.1 The thickness of plate stems at the waterline is to comply with the requirements for plate keels as given in *Pt 6, Ch 3, 3.2 Plate keel*.

5.12.2 The forefoot and stem is to be additionally reinforced with floors.

5.12.3 The cross-sectional area of bar stems, A_{bs}, is not to be taken as less than:

$$A_{bs} = 0,8 k_s L_R \text{ cm}^2$$

where

L_R and k_s are as defined in *Pt 6, Ch 3, 1.5 Symbols and definitions 1.5.1*.

5.13 Transom knee

5.13.1 Centre and side girders are to be bracketed to the transom framing members by means of substantial knees. The face flat of the girders may be gradually reduced to that of the transom stiffening members in accordance with *Figure 3.5.2 Transom knee*.

5.13.2 Hard spots are to be avoided in way of the end connections and care is to be taken to ensure that the stiffening member to which the transom knee is bracketed can satisfactorily carry the transmitted loads.

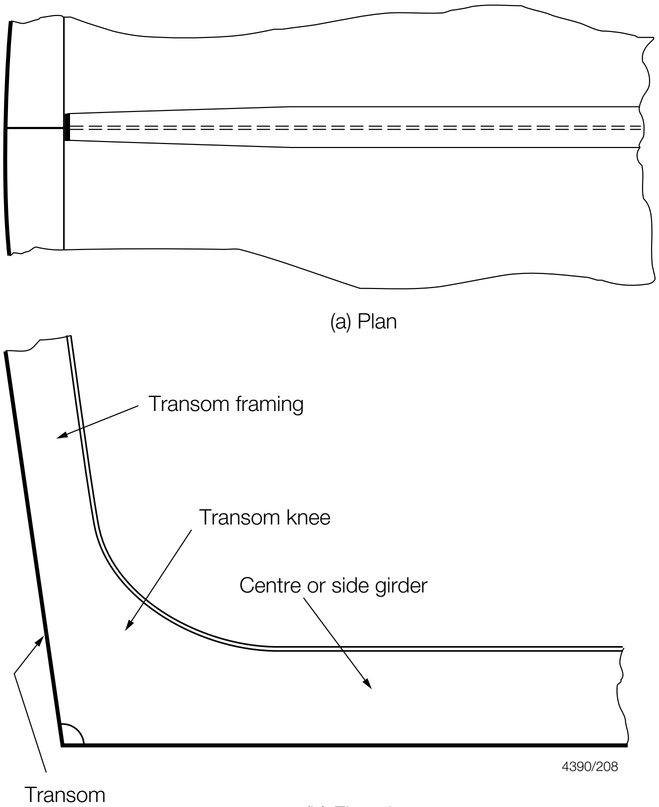


Figure 3.5.2 Transom knee

Section 6
Double bottom structure

6.1 General

6.1.1 The requirements given in this Section provide for double bottom construction of steel mono-hull craft in association with either transverse or longitudinal framing.

6.1.2 Double bottoms are generally to be fitted in accordance with *Pt 3, Ch 2, 6.6 Double and single bottom structure* and where fitted are to extend from the collision bulkhead to the after peak bulkhead, as far as this is practicable within the design and proper working of the craft. In addition, the inner bottom is to be continued to the craft's side in such a manner as to protect the bottom to the turn of bilge or chine.

6.1.3 The double bottom structure in way of girders and duct keels is to be sufficient to withstand the forces imposed by dry-docking the craft.

6.1.4 The centreline girder and side girders are to extend as far forward and aft as practicable and care is to be taken to avoid any abrupt discontinuity. Where girders are cut at bulkheads, their longitudinal strength is to be maintained.

6.1.5 The scantlings of the double bottom structure are to comply with the appropriate minimum requirements given in *Pt 6, Ch 3, 2 Minimum thickness requirements*.

6.2 Keel

6.2.1 The scantlings of bar and plate keels are to comply with the requirements of *Pt 6, Ch 3, 5.3 Centre girder*.

6.2.2 Duct keels, where arranged, are to have a side plate thickness not less than:

$$t_p = \sqrt{k_s}\left(0,008 d_{DB} + 1\right) \text{ mm}$$

but need not be taken as greater than 90 per cent of the centre girder thickness given in *Pt 6, Ch 3, 6.3 Centre girder*.

d_{DB} is the Rule centre girder depth given in *Pt 6, Ch 3, 6.3 Centre girder 6.3.3*.

k_s as defined in *Pt 6, Ch 3, 1.5 Symbols and definitions 1.5.1*.

6.2.3 Where a duct keel forms the boundary of a tank, the requirements of *Pt 6, Ch 3, 7.4 Deep tank plating* and *Pt 6, Ch 3, 7.5 Deep tank stiffening* for deep tanks are to be complied with.

6.2.4 The duct keel width is in general to be 15 per cent of the beam or 2 metres, whichever is the lesser, but in no case is it to be taken as less than 630 mm. The inner bottom and bottom shell within the duct keel are to be suitably stiffened with primary stiffening in the transverse direction, whilst the continuity of the floors is maintained. Access to the duct keel is to be by means of watertight manholes or trunks.

6.3 Centre girder

6.3.1 A centre girder is to be fitted throughout the length of the craft. The web thickness, t_w, is not to be less than that required by:

$$t_w = \sqrt{k_s}\left(0,1L_R + 3\right) \text{ mm within } 0,4L_R \text{ amidships}$$
$$= \sqrt{k_s}\left(0,1L_R + 2\right) \text{ mm at ends}$$

where k_s and L_R as defined in *Pt 6, Ch 3, 1.5 Symbols and definitions 1.5.1*.

6.3.2 The geometric properties of the girder section are to be in accordance with *Pt 6, Ch 3, 1.18 Geometric properties and proportions of stiffener sections*.

6.3.3 The overall depth of the centre girder, d_{DB}, is to be taken as not less than 630 mm and is to be sufficient to give adequate access to all parts of the double bottom.

6.3.4 Additionally, the requirements of *Pt 6, Ch 3, 4.3 Bottom longitudinal primary stiffeners* for bottom longitudinal primary stiffeners are to be complied with.

6.4 Side girders

6.4.1 Where the floor breadth does not exceed 6,0 m, side girders are not required. Vertical stiffeners are to be fitted to the floors on each side, the number and positions of these stiffeners being dependent on the arrangement of the double bottom structure.

6.4.2 Where the breadth of floor is greater than 6,0 m, additional side girders having the same thickness as the floors are to be fitted. The number of side girders is to be such that the distance between the side girders and centre girder and margin plate, or between the side girders themselves, does not exceed 3,0 m.

6.4.3 Side girders where fitted are to extend as far forward and aft as practicable and are in general to terminate in way of bulkheads, deep floors or other primary transverse structure.

6.4.4 Where additional side girders are fitted in way of main machinery seatings, they are to be integrated into the structure of the craft and extended forward and aft as far as practicable.

6.4.5 Under the main engine, girders extending from the bottom shell to the top plate of the engine seating are to be fitted. The height of the girders is to be not less than the height of the floor. Engine holding-down bolts are to be arranged as near as practicable to the girders and floors. Where this cannot be achieved, bracket floors and/or hanging brackets are to be fitted.

6.4.6 Additionally, the requirements of *Pt 6, Ch 3, 4.3 Bottom longitudinal primary stiffeners* for bottom longitudinal primary stiffeners are to be complied with.

6.5 Plate floors

6.5.1 The web thickness of non-watertight plate floors, t_w, is to be not less than:

$$t_w = \sqrt{k_s}\left(0,05L_R + 3,5\right) \text{ mm}$$

where k_s and L_R as defined in *Pt 6, Ch 3, 1.5 Symbols and definitions 1.5.1*.

6.5.2 Additionally, the requirements of *Pt 6, Ch 3, 4.6 Bottom transverse web frames* for bottom transverse web frames stiffeners are to be complied with.

6.5.3 Plate floors are, in general, to be continuous between the centre girder and the margin plate.

6.5.4 In longitudinally framed craft, plate floors or equivalent structure are, in general, to be fitted in the following positions:

(a) At every half frame in way of the main engines, thrust bearings, and bottom of the craft forward.
(b) Outboard of the engine seatings, at every frame within the engine room.
(c) Underneath pillars and bulkheads.
(d) Outside of the engine room at a spacing not exceeding 2,0 m.

6.5.5 Vertical flat bar stiffeners are to be fitted to all plate floors at each longitudinal. Each stiffener is to have a depth of not less than $10t_{w}$ and a thickness of not less than t_{w}, where t_{w} is the thickness of the plate floor as calculated in *Pt 6, Ch 3, 6.5 Plate floors 6.5.1*.

6.5.6 In transversely framed craft, plate floors are to be fitted at every frame in the engine room, under bulkheads, in way of change in depth of double bottom and elsewhere at a spacing not exceeding 2,0 m.

6.6 Bracket floors

6.6.1 Between plate floors, the shell and inner bottom plating is to be supported by bracket floors. The brackets are to have the same thickness as plate floors and are to be stiffened on the unsupported edge.

6.6.2 In longitudinally framed craft, the brackets are to extend from the centre girder and margin plate to the adjacent longitudinal, but in no case is the breadth of the bracket to be taken as not less than 75 per cent of the depth of the centre girder. They are to be fitted at every web frame at the margin plate, and those at the centre girder are to be spaced not more than 1,0 m apart.

6.6.3 In transversely framed craft, the breadth of the brackets, attaching the bottom and inner bottom frames to the centre girder and margin plate, is to be not less than 75 per cent of the depth of the centre girder.

6.7 Watertight floors

6.7.1 The scantlings of watertight floors are to comply with the requirements for plate floors as given in *Pt 6, Ch 3, 6.5 Plate floors*.

6.7.2 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deep tanks as detailed in *Pt 6, Ch 3, 7.3 Watertight bulkhead stiffening* or *Pt 6, Ch 3, 7.5 Deep tank stiffening* respectively.

6.8 Tankside brackets

6.8.1 The scantlings of tankside brackets are to comply with the requirements for plate floors given in *Pt 6, Ch 3, 6.5 Plate floors*.

6.9 Inner bottom plating

6.9.1 The thickness of the inner bottom plating is to be determined from the general plating equation given in *Pt 6, Ch 3, 1.16 Plating general* using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

6.9.2 Inner bottom plating forming the boundaries of tank spaces is, in addition, to comply with the requirements for watertight bulkheads or deeptanks as detailed in *Pt 6, Ch 3, 7.2 Watertight bulkhead plating* or *Pt 6, Ch 3, 7.4 Deep tank plating* respectively. Where the plating forms vehicle, passenger or other decks the requirements of *Pt 6, Ch 3, 8 Deck structures* are to be complied with.

6.10 Inner bottom longitudinals

6.10.1 Inner bottom longitudinals are to be supported by inner bottom transverse web frames, floors, bulkheads or other primary structure, generally spaced not more than 2 m apart.

6.10.2 The inner bottom longitudinals are to be continuous through the supporting structure and are to be satisfactorily stiffened against buckling.

6.10.3 Where it is impracticable to comply with the requirements of *Pt 6, Ch 3, 6.10 Inner bottom longitudinals 6.10.2*, or where it is desired to terminate the inner bottom longitudinals in way of bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

6.10.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 6, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (b).

6.11 Inner bottom transverse web framing

6.11.1 Inner bottom transverse web frames are defined as primary stiffening members which support inner bottom longitudinals. They are to be continuous and to be substantially bracketed at their end connections to bottom web frames, bottom floors and tankside brackets.

6.11.2 Where it is impracticable to comply with the requirements of *Pt 6, Ch 3, 6.11 Inner bottom transverse web framing 6.11.1*, or where it is desired to terminate the inner bottom transverse web frames in way of centre or side girders, bulkheads or integral tank boundaries, etc. they are to be bracketed in way of their end connections, to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

6.11.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 6, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (a).

6.12 Margin plates

6.12.1 A margin plate, if fitted, is to have a thickness as required for inner bottom plating.

6.13 Wells

6.13.1 Small wells constructed in the double bottom structure are not to extend in depth more than necessary. A well extending to the outer bottom may, however, be permitted at the after end of the shaft tunnel of the craft. Other well arrangements (e.g. for lubricating oil under main engines) may be considered provided they give protection equivalent to that afforded by the double bottom.

6.14 Transmission of pillar loads

6.14.1 In double bottoms under widely spaced pillars, the connections of the floors to the girders, and of the floors and girders to the inner bottom, are to be suitably increased. Where pillars are not directly above the intersection of plate floors and girders, partial floors and intercostals are to be fitted as necessary to support the pillars. Manholes are not to be cut in the floors and girders below the heels of pillars. Where longitudinal framing is adopted in the double bottom, equivalent stiffening under the heels of pillars is to be provided, and where the heels of pillars are carried on a tunnel, suitable arrangements are to be made to support the load.

6.15 Manholes

6.15.1 Sufficient manholes are to be cut in the inner bottom, floors and side girders to provide adequate access to, and ventilation of, all parts of the double bottom. The size of the manhole openings is not, in general, to exceed 50 per cent of the double bottom depth unless edge reinforcement is provided. Holes are not to be cut in the centre girder, except in tanks at the forward and after ends of the craft, and elsewhere where tank widths are reduced unless additional stiffening and/or compensation is fitted to maintain the structural integrity.

6.16 Pressure testing

6.16.1 Double bottoms are to be tested upon completion with a head of water representing the maximum internal pressure which could be experienced in service, but not less than a head of water equivalent to the level of the upper deck.

6.17 Drainholes in bottom structure

6.17.1 Sufficient limber holes are to be cut in the internal bottom structure to allow for the drainage of water from all parts of the bilge to the pump suctions.

6.17.2 Particular care is to be given to the positioning of limber holes to ensure adequate drainage and to avoid stress concentrations.

6.17.3 Suitable arrangements are to be made to provide free passage of air from all parts of tanks to the air pipes.

■ *Section 7* Bulkheads and deep tanks

7.1 General

7.1.1 The requirements of this Section apply to a vertical system of stiffening on bulkheads. They may also be applied to a horizontal system of stiffening provided that equivalent support and alignment are provided.

7.1.2 The number and disposition of transverse watertight bulkheads are to be in accordance with *Pt 3, Ch 2, 4 Bulkhead arrangements*.

7.1.3 Bulkheads, or part bulkheads, forming the boundary of tanks are to comply with the requirements of *Pt 6, Ch 3, 7.5 Deep tank stiffening* and *Pt 6, Ch 3, 7.6 Double bottom tanks*.

7.1.4 For bulkheads in way of partially filled holds or tanks, sloshing forces may be required to be taken into account. Where such forces are likely to be significant, the scantlings will be required to be verified by additional calculations.

7.1.5 A centreline bulkhead is, generally, to be fitted in deep tanks which extend from side to side. The bulkhead may be intact or perforated as desired. If intact, the scantlings are to comply with the requirements of *Pt 6, Ch 3, 7.5 Deep tank stiffening* and *Pt 6, Ch 3, 7.6 Double bottom tanks* for tank boundary bulkheads. If perforated, they are to comply with the requirements of *Pt 6, Ch 3, 7.13 Wash plates* for washplates.

7.1.6 The minimum requirements in *Pt 6, Ch 3, 2 Minimum thickness requirements* are to be complied with.

7.2 Watertight bulkhead plating

7.2.1 The thickness of the watertight bulkhead plating is to be determined from the general plating equation given in *Pt 6, Ch 3, 1.16 Plating general* using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

7.3 Watertight bulkhead stiffening

7.3.1 The Rule requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 6, Ch 3, 1.17 Stiffening general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for both non-displacement and displacement craft, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* using the appropriate load model.

7.3.2 Bulkheads are to be suitably strengthened, if necessary, at the ends of deck girders and where subjected to concentrated loads.

7.4 Deep tank plating

7.4.1 The thickness of deep tank plating is to be determined from the general plating equation given in *Pt 6, Ch 3, 1.16 Plating general* using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

7.4.2 A centreline bulkhead is, generally, to be fitted in deep tanks which extend from side to side of the craft. The bulkhead may be intact or perforated as desired. If intact, the plate scantlings are to be as required for boundary bulkheads.

7.5 Deep tank stiffening

7.5.1 Deep tank bulkhead stiffeners are to be bracketed at both ends.

7.5.2 Stiffening on a perforated centreline bulkhead in a tank that extends from side to side may be 50 per cent of that required for boundary bulkheads, using a head measured to the crown of the tank.

7.5.3 The Rule requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 6, Ch 3, 1.17 Stiffening general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for load model (b).

7.6 Double bottom tanks

7.6.1 The scantlings of double bottom tanks are to comply with the requirements for deep tanks given in *Pt 6, Ch 3, 7.4 Deep tank plating* and *Pt 6, Ch 3, 7.5 Deep tank stiffening*.

7.6.2 Where the crown of a double bottom tank forms a vehicle, passenger or other deck, the requirements of *Pt 6, Ch 3, 8 Deck structures* are to be complied with.

7.7 Collision bulkheads

7.7.1 The scantlings of collision bulkheads are to comply with the requirements of *Pt 6, Ch 3, 7.2 Watertight bulkhead plating* and *Pt 6, Ch 3, 7.3 Watertight bulkhead stiffening* except that the thickness of plating and modulus of stiffeners are not to be less than 12 and 25 per cent greater respectively, than required by *Pt 6, Ch 3, 7.2 Watertight bulkhead plating* and *Pt 6, Ch 3, 7.3 Watertight bulkhead stiffening*. If the collision bulkhead forms the boundary of a deep tank or cofferdam then the requirements of *Pt 6, Ch 3, 7.4 Deep tank plating* and *Pt 6, Ch 3, 7.5 Deep tank stiffening* are also to be complied with.

7.8 Gastight bulkheads

7.8.1 Where gastight bulkheads are fitted, in accordance with *Pt 3, Ch 2, 4 Bulkhead arrangements* the scantling requirements for watertight bulkheads are to be complied with.

7.8.2 Gastight bulkheads are to be fitted to protect accommodation spaces from gases and vapour fumes from machinery exhaust and fuel systems.

7.9 Non-watertight or partial bulkheads

7.9.1 Where a bulkhead is structural but non-watertight the scantlings are in general to be as for watertight bulkheads or equivalent in strength to web frames in the same position. Partial bulkheads that are non-structural are outside the scope of LR classification.

7.10 Transmission of pillar loads

7.10.1 Bulkheads that are required to act as pillars in way of underdeck girders and other structures subject to heavy loads are to comply with the requirements of *Pt 6, Ch 3, 10 Pillars and pillar bulkheads*.

7.11 Corrugated bulkheads

7.11.1 The plating thickness and section modulus for symmetrical corrugated bulkheads are to be in accordance with watertight bulkheads or deep tank bulkheads as appropriate. The spacing, s, is to be taken as s_c, as defined in, *Figure 2.3.1 Corrugation* in Pt 3, Ch 2.

7.11.2 In addition, the section geometric properties of *Pt 6, Ch 3, 1.18 Geometric properties and proportions of stiffener sections* are to be complied with.

7.11.3 The actual section modulus may be derived in accordance with *Pt 3, Ch 2, 3.2 Geometric properties of sections*.

7.12 Stiffeners passing through bulkheads

7.12.1 Primary longitudinal stiffening members are to be continuous through transverse bulkheads.

7.12.2 Pipe or cable runs through watertight bulkheads are to be fitted with suitable watertight glands.

7.13 Wash plates

7.13.1 Tanks are to be sub-divided as necessary by internal baffles or wash plates. Baffles or wash plates which support hull framing are to have scantlings equivalent to web frames in the same position.

7.13.2 Wash plates and wash bulkheads are, in general, to have an area of perforation not less than 10 per cent of the total area of the bulkhead. The perforations are to be so arranged that the efficiency of the bulkhead as a support is not impaired.

7.13.3 The plate thickness is to be not less than the structural element from which the wash bulkhead is formed.

7.13.4 The general stiffener requirements are to be in accordance with *Pt 6, Ch 3, 7.5 Deep tank stiffening*. However, the section modulus may be 50 per cent of that required by *Pt 6, Ch 3, 7.5 Deep tank stiffening*.

7.14 Cofferdams

7.14.1 A cofferdam is to be fitted between freshwater and fuel oil or sanitary tanks. The scantlings of cofferdams are to comply with the requirements of deep tank bulkheads or non-watertight bulkheads as appropriate.

7.15 Coatings

7.15.1 Integral freshwater and fuel oil tanks are to be cleaned and dried after testing and then treated with a suitable coating, in accordance with the manufacturer's recommendations.

7.16 Air pipes

7.16.1 Air pipes of sufficient number and area are to be fitted to each tank in accordance with *Pt 15, Ch 2, 11 Air, overflow and sounding pipes*.

7.17 Fire protection

7.17.1 Fire protection requirements given in *Pt 17 Fire Protection, Detection and Extinction* are to be complied with.

7.18 Access

7.18.1 Compartments within the craft are to be sufficiently accessible to allow for maintenance and future structural surveys. Linings on craft sides, deckheads and bulkheads, etc. must be capable of being removed. Sufficient space is to be available below lower decks/soles to allow access to the bottom structure. An adequate number of manholes, removable panels, etc. are to provided.

7.18.2 Doors and hatches fitted through watertight bulkheads are to be of equivalent construction to the bulkhead in which they are fitted, be permanently attached and capable of being closed watertight from both sides of the bulkhead. They are to be tested watertight.

7.18.3 Doors and hatches are not to be fitted in collision bulkheads, except in craft of less than 21 metres Rule length, L_R, or in the case where it would be impracticable to arrange access to the forepeak other than through the collision bulkhead. Where fitted, the doors and hatches are to be watertight, as small as practicable and open into the forepeak compartment. Doors in collision bulkheads are to be kept closed at all times while the craft is at sea, *see Pt 3, Ch 2, 4.3 Collision bulkhead 4.3.4*.

7.18.4 Particular care is to be given to the design and workmanship of the tanks, and adequate access manholes are to be fitted, *see Pt 3, Ch 1, 7 Inspection, workmanship and testing procedures*.

7.19 Testing

7.19.1 Deep tanks are to be tested on completion, with a head of water to the top of the overflow, or 1,8 m above the crown of the tank, whichever is the greater. The pressure to which the tanks will be subjected to in service is to be indicated on the plans submitted.

■ *Section 8*
Deck structures

8.1 General

8.1.1 The deck plating is to be supported by transverse beams with fore and aft girders or by longitudinals with deep transverse beams. The transverse and deep transverse beams are to align with side main frames and side web frames respectively.

8.1.2 Beams are to be fitted at every frame and bracketed to the frames. Strong beams and deep transverse beams are to align with and be effectively connected to the side web frames. They are also to be fitted at the ends of large openings in the deck.

8.1.3 The deck plating and supporting structure are to be suitably reinforced in way of cranes, masts, derrick posts and deck machinery.

8.1.4 Primary stiffening members are to be continuous and substantially bracketed at their end connections to maintain continuity of structural strength.

8.1.5 Secondary stiffening members are to be effectively continuous and bracketed at their end connections as appropriate.

8.1.6 Primary and secondary stiffener end connection arrangements are, in general, to be in accordance with *Pt 6, Ch 3, 1.22 Primary member end connections* and *Pt 6, Ch 3, 1.20 Secondary member end connections*, respectively.

8.1.7 The ends of beams, longitudinals, girders and transverses are to be effectively built into the adjacent structure, or equivalent arrangements provided.

8.1.8 Tripping brackets are to be fitted on deep webs.

8.1.9 Deck structures subject to concentrated loads, are to be suitably reinforced. Where concentrations of loading on one side of a stiffening member may occur, such as pillars out of line, the member is to be adequately stiffened against torsion. Additional reinforcements may be required in way of localised areas of high stress.

8.1.10 The thickness of the deck plating is in no case to be less than the appropriate minimum requirement given in *Pt 6, Ch 3, 2 Minimum thickness requirements*.

8.1.11 The geometric properties of stiffener sections are to be in accordance with *Pt 6, Ch 3, 1.18 Geometric properties and proportions of stiffener sections*.

8.2 Strength/Weather deck plating

8.2.1 The thickness of strength/weather deck plating is to be determined from the general plating equation given in *Pt 6, Ch 3, 1.16 Plating general* using the design pressure head from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

8.2.2 The scantlings of watertight cockpits are to be of equivalent strength to those of the strength/weather deck, *see also Pt 4 Additional Requirements for Yachts*.

8.2.3 It is recommended that the working areas of the weather deck have an anti-slip surface.

8.2.4 Where decks are sheathed with wood or other materials, details of the method of attachment are to be submitted, *see also Pt 6, Ch 3, 2.4 Sheathing*.

8.3 Lower deck/Inside deckhouse plating

8.3.1 The thickness of the lower deck/inside deckhouse plating is to be determined from the general plating equation given in *Pt 6, Ch 3, 1.16 Plating general* using the design pressure head from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

8.4 Accommodation deck plating

8.4.1 Accommodation decks are in general to be treated as lower deck/inside deckhouse decks, with their plating requirements determined in accordance with *Pt 6, Ch 3, 8.3 Lower deck/Inside deckhouse plating*.

8.5 Cargo deck plating

8.5.1 The thickness of cargo deck plating is to be determined from the general plating equation given in *Pt 6, Ch 3, 1.16 Plating general* using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

8.5.2 For vehicle decks, plating thickness requirements are to comply with the requirements of *Pt 6, Ch 3, 5.3 Centre girder*.

8.6 Decks forming crowns of tanks

8.6.1 Decks forming the crown of tanks are to comply with the requirements for the appropriate deck, and are to be additionally examined for compliance with the requirements for deep tank plating given in *Pt 6, Ch 3, 7.4 Deep tank plating*.

8.7 Strength/Weather deck stiffening

8.7.1 The Rule requirements for section modulus, inertia and web area for the **strength/weather deck primary stiffening** are to be determined from the general equations given in *Pt 6, Ch 3, 1.17 Stiffening general*, using the design pressure heads from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (a).

8.7.2 The Rule requirements for section modulus, inertia and web area for the **strength/weather deck secondary stiffening** are to be determined from the general equations given in *Pt 6, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.7.3 Longitudinal framing is, in general, to be adopted at the strength deck outside line of openings, but special consideration will be given to proposals for transverse framing.

8.8 Lower deck/Inside deckhouse stiffening

8.8.1 The Rule requirements for section modulus, inertia and web area for lower deck/inside deckhouse stiffening are to be determined from the general equations given in *Pt 6, Ch 3, 1.17 Stiffening general* using the design pressure head from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients*. Primary members are assumed to be load model (a) and secondary members load model (b). However, special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.9 Accommodation deck stiffening

8.9.1 Accommodation decks are in general to be treated as lower deck/inside deckhouse decks, with their scantling requirements determined in accordance with *Pt 6, Ch 3, 8.8 Lower deck/Inside deckhouse stiffening*.

8.10 Cargo deck stiffening

8.10.1 The Rule requirements for section modulus, inertia and web area for cargo deck stiffening are to be determined from the general equations given in *Pt 6, Ch 3, 1.17 Stiffening general* using the design pressure head from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients*. Primary members are assumed to be load model (a) and secondary members load model (b). However, special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.10.2 In addition, where the cargo comprises wheeled vehicles, the requirements of *Pt 6, Ch 5, 3 Vehicle decks* are to be complied with.

8.11 Deck openings

8.11.1 All openings are to be supported by an adequate framing system, pillars or cantilevers. When cantilevers are used scantlings may be derived from direct calculations.

8.11.2 Where stiffening members terminate in way of an opening they are to be attached to carlings, girders, transverses or coaming plates.

8.11.3 The corners of large hatchways in the strength/weather deck within $0{,}5L_R$ amidships are to be elliptical, parabolic or rounded, with a radius generally not less than 1/24 of the breadth of the opening.

8.11.4 Where elliptical corners are arranged, the major axis is to be fore and aft, the ratio of the major to minor axis is to be not less than two to one nor greater than 2.5 to 1, and the minimum half-length of the major axis is to be defined by l_1 in *Figure 3.8.1 Hatch opening geometry*. Where parabolic corners are arranged, the dimensions are also to be as shown in *Figure 3.8.1 Hatch opening geometry*.

8.11.5 Where the corners are parabolic or elliptical, insert plates are not required.

8.11.6 For other shapes of corner, insert plates of the size and extent shown in *Figure 3.8.2 Inserts in way of hatch opening* will, in general, be required. The required thickness of the insert plate is to be not less than 25 per cent greater than the adjacent deck thickness, outside line of openings.

8.11.7 For lower decks the corners of large openings are to be rounded, with a radius generally not less than 1/24 of the breadth of the opening.

8.11.8 Insert plates will be required at lower decks in way of any rapid change in hull form to compensate for loss of deck cross-sectional area. Otherwise, insert plates will not normally be required.

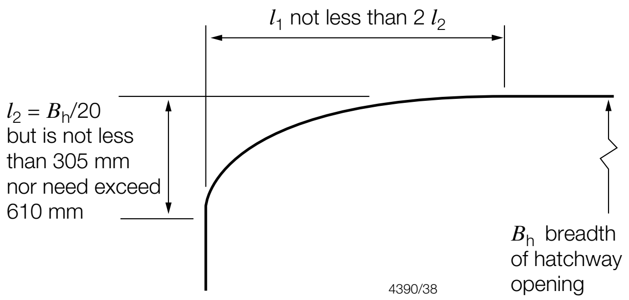


Figure 3.8.1 Hatch opening geometry

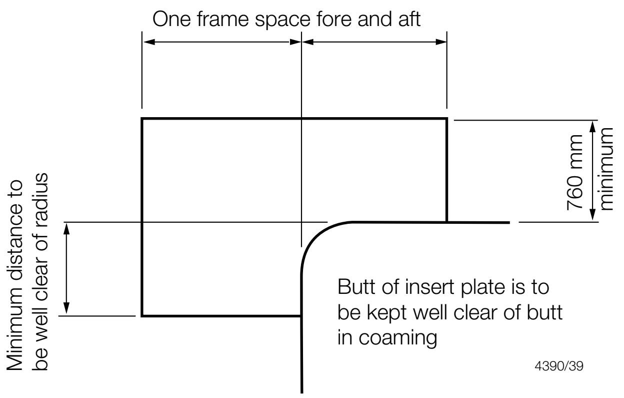


Figure 3.8.2 Inserts in way of hatch opening

8.11.9 Adequate transverse strength is to be provided in the deck area between large hatch openings, subjected to transverse and buckling loads.

8.11.10 The requirements for closing arrangements and outfit are given in *Pt 3, Ch 4 Closing Arrangements and Outfit*.

8.12 Sheathing

8.12.1 The requirements for deck sheathing given in *Pt 6, Ch 3, 2.4 Sheathing* are to be complied with.

8.13 Novel features

8.13.1 Where large or novel hatch openings are proposed, detailed calculations are to be submitted to demonstrate that the scantlings and arrangements in way of the openings are adequate to maintain continuity of structural strength.

Section 9
Superstructures, deckhouses and bulwarks

9.1 General

9.1.1 Where practicable, superstructures and deckhouses are to be designed with well cambered decks and well radiused corners to build rigidity into the structure.

9.1.2 The plating and supporting structure are to be suitably reinforced in way of localised areas of high stress such as corners of openings, cranes, masts, derrick posts, machinery, fittings and other heavy or vibrating loads.

9.1.3 Primary stiffening members are to be continuous and substantially bracketed at their end connections to maintain continuity of structural strength.

9.1.4 Secondary stiffening members are to be effectively continuous and bracketed at their end connections as appropriate.

9.1.5 Structures subject to concentrated loads are to be suitably reinforced. Where concentrations of loading on one side of a stiffener may occur, such as pillars out of line, the stiffener is to be adequately stiffened against torsion.

9.1.6 The plating thickness of superstructures, deckhouses and bulwarks is in no case to be less than the appropriate minimum requirement given in *Pt 6, Ch 3, 2 Minimum thickness requirements*.

9.1.7 Stiffener sections and geometric properties are to be in accordance with *Pt 6, Ch 3, 1.18 Geometric properties and proportions of stiffener sections*.

9.2 Symbols and definitions

9.2.1 The term `house' is used in this Section to include both superstructures and deckhouses.

9.2.2 The symbols applicable to this Section are defined in *Pt 6, Ch 3, 1.5 Symbols and definitions 1.5.1*.

9.3 House side plating

9.3.1 The thickness of house side plating is to be determined from the general plating equation given in *Pt 6, Ch 3, 1.16 Plating general* using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

9.4 House front plating

9.4.1 The thickness of the house front plating is to be determined from the general plating equation given in *Pt 6, Ch 3, 1.16 Plating general* using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

9.5 House end plating

9.5.1 The thickness of the house end plating is to be determined from the general plating equation given in *Pt 6, Ch 3, 1.16 Plating general* using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

9.6 House top plating

9.6.1 The thickness of the house top plating is to be determined from the general plating equation given in *Pt 6, Ch 3, 1.16 Plating general* using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

9.7 Coachroof plating

9.7.1 The thickness of the coachroof plating is to be determined from the general plating equation given in *Pt 6, Ch 3, 1.16 Plating general* using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

9.8 Machinery casing plating

9.8.1 The thickness of the plating of machinery casings is to be determined from the general plating equation given in *Pt 6, Ch 3, 1.16 Plating general* using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

9.9 Forecastle requirements

9.9.1 The forecastle side plating may be a continuation of the hull side shell plating or fitted as a separate assembly. In both cases the plating thickness is to be the same as the side shell plating at deck edge. Where fitted as a separate assembly, suitable arrangements are to be made to ensure continuity of the effect of the sheerstrake at the break and at the upper edge of the forecastle side. Full penetration welding is to be used.

9.9.2 The side plating is to be stiffened by side frames effectively connected to the deck structure. Deep webs are to be fitted to ensure overall rigidity.

9.9.3 The deck plating thickness is to be increased by 20 per cent in way of the end of the forecastle if this occurs at a position aft of 0,25L_R from the FP. No increase is required if the forecastle end bulkhead lies forward of 0,2$L_R$from the FP The increase at intermediate positions of end bulkhead is to be obtained by interpolation.

9.10 House side stiffeners

9.10.1 The Rule requirements for section modulus, inertia and web area for the **house side primary stiffening** are to be determined from the general equations given in *Pt 6, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (a).

9.10.2 The Rule requirements for section modulus, inertia and web area for **house side secondary stiffening** are to be determined from the general equations given in *Pt 6, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.11 House front stiffeners

9.11.1 The Rule requirements for section modulus, inertia and web area for **house front primary stiffening** are to be determined from the general equations given in *Pt 6, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (a).

9.11.2 The Rule requirements for section modulus, inertia and web area for **house front secondary stiffening** are to be determined from the general equations given in *Pt 6, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.12 House aft end stiffeners

9.12.1 The Rule requirements for section modulus, inertia and web area for **house aft end primary stiffening** are to be determined from the general equations given in *Pt 6, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (a).

9.12.2 The Rule requirements for section modulus, inertia and web area for **house aft end secondary stiffening** are to be determined from the general equations given in *Pt 6, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.13 House top stiffeners

9.13.1 The house top is to be effectively supported by a system of transverse or longitudinal beams and girders. The span of the beams is in general not to exceed 2,4 m and the beams are to be effectively connected to the house upper coamings and girders.

9.13.2 The Rule requirements for section modulus, inertia and web area for **house top primary stiffening** are to be determined from the general equations given in *Pt 6, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (a).

9.13.3 The Rule requirements for section modulus, inertia and web area for **house top secondary stiffening** are to be determined from the general equations given in *Pt 6, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.14 Coachroof stiffeners

9.14.1 The Rule requirements for section modulus, inertia and web area for **coachroof primary stiffening** are to be determined from the general equations given in *Pt 6, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (a).

9.14.2 The Rule requirements for section modulus, inertia and web area for **coachroof secondary stiffening** are to be determined from the general equations given in *Pt 6, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.15 Machinery casing stiffeners

9.15.1 The Rule requirements for section modulus, inertia and web area for **machinery casing primary stiffening** are to be determined from the general equations given in *Pt 6, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (a).

9.15.2 The Rule requirements for section modulus, inertia and web area for **machinery casing secondary stiffening** are to be determined from the general equations given in *Pt 6, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.15.3 Where casing sides act as girders supporting decks, care is to be taken that access openings do not seriously weaken the structure. Openings are to be effectively framed and reinforced if found necessary. Particular care is to be paid to stiffening where the casing supports the funnel or exhaust uptakes.

9.15.4 Where casing stiffeners carry loads from deck transverses, girders, etc. or where they are in line with pillars below, they are to be suitably reinforced.

9.16 Forecastle stiffeners

9.16.1 The scantlings of forecastle primary and secondary stiffening members are to be equivalent to those for the side shell envelope framing at the deck edge as required by *Pt 6, Ch 3, 4 Shell envelope framing*.

9.17 Superstructures formed by extending side structures

9.17.1 Superstructure first tier sides formed by extending the hull side structure are to be in accordance with the requirements for house fronts given in *Pt 6, Ch 3, 9.4 House front plating* and *Pt 6, Ch 3, 9.11 House front stiffeners* for plating and stiffeners

respectively, but need not be taken as greater than the side structure requirements at the deck edge at the same longitudinal position.

9.18 Fire aspects

9.18.1 The requirements for fire detection, protection and extinction are given in *Pt 17 Fire Protection, Detection and Extinction*.

9.19 Openings

9.19.1 All openings are to be substantially framed and have well rounded corners. Arrangements are to be made to minimise the effect of discontinuities in erections. Continuous coamings or girders are to be fitted below and above doors and similar openings.

9.19.2 Particular care is to be paid to the effectiveness of end bulkheads, and the upper deck stiffening in way, when large openings for doors and windows are fitted.

9.19.3 Special care is to be taken to minimise the size and number of openings in the side bulkheads in the region of the ends of erections within 0,5L_R amidships. Account is to be taken of the high vertical shear loading which can occur in these areas.

9.19.4 For closing arrangements and outfit the requirements are given in *Pt 3, Ch 4 Closing Arrangements and Outfit*.

9.20 Mullions

9.20.1 Window openings are to be suitably framed and mullions will in general be required.

9.20.2 The scantlings of mullions are to be not less than as required for a stiffener in the same position.

9.20.3 When determining the stiffener requirements, the width of effective plating is in no case to be taken as greater than the distance between adjacent window openings.

9.20.4 Where significant shear forces are to be vertically transmitted by the window frames, adequate shear rigidity is to be verified by direct calculation.

9.21 Global strength

9.21.1 Transverse rigidity is to be maintained throughout the length of the erection by means of web frames, bulkheads or partial bulkheads. Particular care is to be paid when an upper tier is wider than its supporting tier and when significant loads are carried on the house top.

9.21.2 Where practicable, web frames are to be arranged in line with bulkheads below.

9.21.3 Internal bulkheads are to be fitted in line with bulkheads or deep primary stiffeners below.

9.22 House/deck connection

9.22.1 Adequate support under the ends of erections is to be provided in the form of webs, pillars, diaphragms or bulkheads in conjunction with reinforced deck beams.

9.22.2 Special attention is to be given to the connection of the erection to the deck in order to provide an adequate load distribution and avoid stress concentrations.

9.22.3 Connections between the erection and the deck by means of bimetallic joints are to comply with *Pt 6, Ch 2, 4.23 Triaxial stress considerations*.

9.22.4 Typical design details of house/deck connections are given in LR's *Guidance Notes for Structural Details*.

9.23 Sheathing

9.23.1 Sheathing arrangements are to comply with the requirements of *Pt 6, Ch 3, 2.4 Sheathing*.

9.24 Erections contributing to longitudinal strength

9.24.1 For craft above 40 m in length, L_R, or for designs where the superstructure is designed to absorb global loads the effectiveness of superstructures to carry these loads is to be determined. The effectiveness may be assessed in accordance with *Pt 6, Ch 6, 2.5 Torsional strength*.

9.24.2 Where *Pt 6, Ch 3, 9.17 Superstructures formed by extending side structures* applies and the first or second tier is regarded as the strength deck according to *Pt 6, Ch 6, 2.5 Torsional strength*, the hull upper deck scantlings at the forward and aft ends of the superstructure may need to be increased due to the lesser efficiency of the superstructure tiers at their ends. The scantlings of the side structure in way of these areas may also be required to be increased.

9.24.3 When large openings or a large number of smaller openings are cut in the superstructure sides, reducing the capability to transmit shear force between decks, an assessment or structural efficiency may be required.

9.25 Novel features

9.25.1 Direct calculations may be required to determine the plating and stiffener requirements where the house is of unusual design, form or proportions.

9.26 Bulwarks

9.26.1 General requirements for bulwarks are given in *Pt 3, Ch 4, 8 Bulwarks, guard rails and other means for the protection of crew*.

9.26.2 The thickness of the bulwark plating is to be determined from the general plating equation given in *Pt 6, Ch 3, 1.16 Plating general* using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

9.26.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 6, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (d).

9.26.4 Bulwarks are not to be cut for gangway or other openings near the breaks of superstructures.

9.26.5 Attention is to be paid to avoid discontinuity of strength of the bulwark, particularly in way of local increases in stress and changes in height.

9.26.6 Welding of bulwark to the top edge of sheer-strake within $0,5L_R$ amidship, is generally to be avoided. However, if this arrangement is not practicable welding to the sheerstrake may be accepted if care is taken to minimise any notch effects.

9.26.7 **Fishing craft** are to have bulwarks fitted. The bulwark may be formed from a continuation of the side shell plating or connected as a separate assembly. Where the bulwark is considered to be stressed and contributing to the global strength of the craft, the plate thickness of the bulwark is not to be less than the sheer-strake thickness. In no case is the thickness of the bulwark plating to be taken as less than 80 per cent of the side shell thickness. The bulwark is to be supported by suitable stiffening members which may be formed from a continuation of the side frames, or from flanged plate stays of the same thickness as the bulwark. In general these frames are to be spaced not more than two side frame spacings apart.

9.26.8 In way of gantries, trawl gallows, mooring pipes etc. the plate thickness in way is to be increased by not less than 50 per cent.

9.26.9 **Pilot craft** are to be fitted with sufficient hand rails adjacent to the exposed areas of the working decks and platforms. In addition these areas are to have non-skid surfaces.

9.27 Freeing arrangements

9.27.1 Requirements for freeing arrangements are given in *Pt 3, Ch 4, 9 Deck drainage*.

9.28 Free flow area

9.28.1 The requirements for the free flow area are given in *Pt 3, Ch 4, 9.3 Free flow area*.

9.29 Guard rails

9.29.1 The requirements for guard rails are given in *Pt 3, Ch 4, 8.4 Guard rails*.

Section 10
Pillars and pillar bulkheads

10.1 Application

10.1.1 Pillars are to be arranged to transmit loads from decks and superstructures into the bottom structure. Pillars are generally to be constructed from solid, tubular, or **I** beam section. A pillar may be a fabricated trunk or partial bulkhead.

10.2 Determination of span length

10.2.1 The effective span length of the pillar, l_{ep}, is in general the distance between the head and heel of the pillar. Where substantial brackets are fitted, l_{ep} may be reduced by 2/3 the depth of the bracket at each end.

10.3 Head and heel connections

10.3.1 Pillars are to be attached at their heads to plates supported by efficient brackets, in order to transmit the load effectively. Doubling or insert plates are to be fitted to decks under large pillars and to the inner bottom under the heels of tubular or hollow square pillars. The pillars are to have a bearing fit and are to be attached to the head and heel plates by continuous welding. At the heads and heels of pillars built of rolled sections, the load is to be well distributed by means of longitudinal and transverse brackets.

10.4 Alignment and arrangement

10.4.1 Pillars are to be located on main structural members. They are in general to be fitted below windlasses, winches, capstans, the corners of deckhouses and elsewhere where considered necessary.

10.4.2 Wherever possible, deck pillars are to be fitted in the same vertical line as pillars above and below, and effective arrangements are to be made to distribute the load at the heads and heels of all pillars.

10.4.3 Where pillars support eccentric loads, or are subjected to lateral pressures, they are to be suitably strengthened for the additional bending moment imposed upon them.

10.4.4 Doublers are generally to be fitted on decks and inner bottoms, other than within tanks where doublers are not allowed. Brackets may be used instead of doublers.

10.5 Minimum thickness

10.5.1 The minimum wall thickness of hollow pillars is to be taken as not less than 1/20 of the external dimension of the pillar.

10.6 Design loads

10.6.1 The design loading, P_p, to be used in the determination of pillar scantlings is as follows:

$$P_p = S_{gt} b_{gt} P_c + P_a \text{ kN}$$

where

P_p = design load supported by the pillar, to be taken as not less than 5 kN

P_c = basic deck girder design pressure, as appropriate, plus any other loadings directly above the pillar, in kN/m^2

P_a = load, in kN, from pillar or pillars above, assumed zero if there are no pillars over

S_{gt} = spacing, or mean spacing, of girders or transverses, in metres

b_{gt} = distance between centres of two adjacent spans of girders or transverses supported by the pillar, in metres

10.7 Scantlings determination

10.7.1 The cross-sectional area of the pillar, A_p, is not to be less than:

$$A_p = 10\frac{P_p}{\sigma_p}\ \text{cm}^2$$

where

P_p = design load, in kN, supported by the pillar as determined from *Pt 6, Ch 3, 10.8 Maximum slenderness ratio*

σ_p = permissible compressive stress, in N/mm^2

$$= \frac{f_p \sigma_s}{1 + 0,0051\, \sigma_s k_f \left(\frac{l_{ep}}{r}\right)^2}\ \text{N/mm}^2$$

where

f_p = pillar location factor defined in *Table 3.10.1 Pillar location factors*

σ_s = specified minimum yield strength of the material, in N/mm^2

k_f = pillar end fixity factor

= 0,25 for full fixed/bracketed

= 0,50 for partially fixed

= 1,0 for free ended

r = least radius of gyration of pillar cross-section, in cm

$$= \frac{I_p}{A_p}\ \text{cm}$$

I_p = least moment of inertia of cross-section of pillar or stiffener/plate combination, in cm^4

l_{ep} = effective span of pillar, in metres, or bulkhead as defined in *Pt 6, Ch 3, 10.2 Determination of span length*.

Table 3.10.1 Pillar location factors

Location	f_p
Supporting weather deck	0,50
Supporting vehicle deck	0,50
Supporting passenger deck	0,50
Supporting lower/inner deck	0,75
Supporting coachroof	0,75
Supporting deckhouse top	1,00

10.8 Maximum slenderness ratio

10.8.1 The slenderness ratio (l_{ep}/r) of pillars is not to be taken greater than 1,1. Where l_{ep} and r are as defined in *Pt 6, Ch 3, 10.7 Scantlings determination 10.7.1*. Pillars with slenderness ratio in excess of 1,1 may be accepted subject to special consideration on a case by case basis and provided that the remaining requirements of the Rules are complied with.

10.9 Pillars in tanks

10.9.1 In no circumstances are pillars to pass through tanks. Where loads are to be transmitted through tanks, pillars within the tanks are to be carefully aligned with the external pillars.

10.9.2 Pillars within tanks are, in general, to be of solid cross section. Where it is proposed to use hollow section pillars each case will be subject to special consideration and the scantlings as determined from the Rules may require to be increased

dependent upon the material to be used, the fluid contained and the arrangement of the pillars. Hollow pillars are to be adequately drained and vented.

10.9.3 Where pillars within tanks may be subjected to tensile stresses due to hydrostatic pressure, the design is to provide sufficient welding to withstand the tensile load imposed.

10.9.4 Doubling plates at ends of pillars within tanks are not acceptable.

10.10 Pillar bulkheads

10.10.1 The stiffener/plate combination used in the determination of pillar bulkhead scantlings is to be that of a stiffener with an effective width of attached plating as determined from *Pt 6, Ch 3, 1.11 Other materials*.

10.10.2 The cross-sectional area of the pillar bulkhead, A_{pb}, is to be determined in accordance with *Pt 6, Ch 3, 10.7 Scantlings determination* using the design loading, P_{pb}, as follows:

$$P_{pb} = S_{bs} b_{pb} P_c + P_a \text{ kN}$$

where

P_{pb} = design load supported by the stiffener plate combination of the pillar bulkhead

P_c = basic deck girder design pressure, as appropriate, plus any other loadings directly above the pillar, in kN/m^2

S_{bs} = spacing, or mean spacing, of bulkheads or effective transverses/longitudinal stiffeners, in metres

b_{pb} = distance between centres of two adjacent spans of girders or transverses supported by the pillar bulkhead, in metres, and can be taken as the distance between pillar bulkhead stiffeners where the stiffeners at the top of the bulkhead effectively distributes the load evenly into the stiffeners

10.10.3 The thickness of the bulkhead plating is in no case to be taken as less than 4 mm.

10.11 Direct calculations

10.11.1 As an alternative to *Pt 6, Ch 3, 10.6 Design loads*, pillars may be designed on the basis of direct calculation. The method adopted and the stress levels proposed for the material of construction are to be submitted together with the calculations for consideration.

10.12 Fire aspects

10.12.1 Pillars and pillar bulkheads are to be suitably protected against fire, and, where necessary, be self-extinguishing or capable of resisting fire damage. All pillars are to comply with the requirements of *Pt 17 Fire Protection, Detection and Extinction*.

10.13 Novel features

10.13.1 Where unusual or novel pillar designs are proposed that are unable to comply with the requirements of this Section, their design together with the direct calculations are to be submitted for special consideration.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to multi-hull craft of steel construction as defined in *Ch 1, 1 Background*.

1.2 General

1.2.1 Except as otherwise specified within this Chapter, the scantlings and arrangements of multi-hull craft are to be determined in accordance with the procedures described in, or required by *Pt 6, Ch 3 Scantling Determination for Mono-Hull Craft* for mono-hull craft, using the pressures from *Pt 5 Design and Load Criteria* appropriate to multi-hulls.

1.3 Direct calculations

1.3.1 Where the craft is of unusual design, form or proportions, or where the speed of the craft exceeds 60 knots the scantlings are to be determined by direct calculation.

1.3.2 The requirements of this Chapter may be modified where direct calculation procedures are adopted to analyse the stress distribution in the primary structure.

1.4 Equivalents

1.4.1 Lloyd's Register (hereinafter referred to as 'LR') will consider direct calculations for the derivation of scantlings as an alternative and equivalent to those derived by Rule requirements in accordance with *Pt 3, Ch 1, 3 Equivalents*.

1.5 Symbols and definitions

1.5.1 The symbols used in this Chapter are defined below and in the appropriate Section:

L_R = Rule length of craft, in metres

s = stiffener spacing, in mm

t_p = plating thickness, in mm

k_s = higher tensile factor, as defined in *Pt 6, Ch 2, 2.4 Mechanical properties for design*

σ_s = specified minimum yield strength of the material, in N/mm^2.

1.5.2 **Bottom outboard.** For high speed craft, where the scantlings of the bottom shell are governed by impact pressure considerations, the bottom outboard shell is defined as the area of the hull between the outboard edge of the keel and the outer bilge tangential point. For displacement and semi displacement type craft where the scantlings of the bottom shell are governed by either hydrostatic or pitching pressures the bottom outboard shell is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

1.5.3 **Bottom inboard.** For high speed craft, where the scantlings of the bottom shell are governed by impact pressure considerations, the bottom inboard shell is defined as the area of the hull between the inboard edge of the keel and the inner bilge tangential point. For displacement and semi displacement type craft where the scantlings of the bottom shell are governed by either hydrostatic or pitching pressures the bottom inboard shell is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

1.5.4 **Cross-deck.** The cross-deck is defined as the structure which forms the bridge connection between any two adjacent hulls.

1.5.5 **Haunch.** The haunch is defined as the transition area between the cross-deck and the inboard side shell plating.

1.5.6 **Side inboard.** The side inboard is defined as the area between the bottom inboard shell and the wet-deck (or lower edge of the haunches, where fitted).

1.5.7 **Side outboard.** The side outboard is defined as the area between bottom outboard shell and the deck at side.

1.5.8 **Wet-deck.** The wet-deck is defined as the area between the upper edges of the side inboard plating (or upper edges of the haunches, where fitted).

■ *Section 2*
Minimum thickness requirements

2.1 General

2.1.1 Unless otherwise specified in this Section, the requirements of *Pt 6, Ch 3, 2 Minimum thickness requirements* are to be complied with.

2.1.2 The thickness of plating and stiffeners determined from the Rule requirements is in no case to be less than the appropriate minimum requirement given in *Table 4.2.1 Minimum thickness requirements* for craft type.

2.1.3 In addition, where plating contributes to the global strength of the craft, the thickness is to be not less than that required to satisfy global strength requirements.

Table 4.2.1 Minimum thickness requirements

Item	Minimum thickness (mm)		
	Catamaran	Multi-hull	Swath
Shell envelope			
Bottom shell plating	$\omega\sqrt{k_{ms}}\left(0,4\sqrt{L_R}+2,0\right) \geq 3,5\,\omega$	$\omega\sqrt{k_{ms}}\left(0,4\sqrt{L_R}+2,0\right) \geq 3,5\,\omega$	$\omega\sqrt{k_{ms}}\left(0,4\sqrt{L_R}+2,0\right) \geq 3,5\,\omega$
Side shell plating	$\omega\sqrt{k_{ms}}\left(0,38\sqrt{L_R}+1,2\right) \geq 3,0\,\omega$	$\omega\sqrt{k_{ms}}\left(0,38\sqrt{L_R}+1,2\right) \geq 3,0\,\omega$	$\omega\sqrt{k_{ms}}\left(0,38\sqrt{L_R}+1,2\right) \geq 3,0\,\omega$
Wet-deck plating	$\omega\sqrt{k_{ms}}\left(0,38\sqrt{L_R}+1,2\right) \geq 3,0\,\omega$	$\omega\sqrt{k_{ms}}\left(0,38\sqrt{L_R}+1,2\right) \geq 3,0\,\omega$	$\omega\sqrt{k_{ms}}\left(0,38\sqrt{L_R}+1,2\right) \geq 3,0\,\omega$
Single bottom structure			
Centre girder web	$\omega\sqrt{k_{ms}}\left(0,8\sqrt{L_R}+1,0\right) \geq 4,0\,\omega$	$\omega\sqrt{k_{ms}}\left(0,8\sqrt{L_R}+1,0\right) \geq 4,0\,\omega$	$\omega\sqrt{k_{ms}}\left(0,8\sqrt{L_R}+1,0\right) \geq 4,0\,\omega$
Floor webs	$\omega\sqrt{k_{ms}}\left(0,6\sqrt{L_R}+0,8\right) \geq 3,5\,\omega$	$\omega\sqrt{k_{ms}}\left(0,6\sqrt{L_R}+0,8\right) \geq 3,5\,\omega$	$\omega\sqrt{k_{ms}}\left(0,6\sqrt{L_R}+0,8\right) \geq 3,5\,\omega$

Side girder webs	$\omega\sqrt{k_{ms}}\left(0,6\sqrt{L_R}+0,8\right)\geq 3,5\,\omega$	$\omega\sqrt{k_{ms}}\left(0,6\sqrt{L_R}+0,8\right)\geq 3,5\,\omega$	$\omega\sqrt{k_{ms}}\left(0,6\sqrt{L_R}+0,8\right)\geq 3,5\,\omega$
Double bottom structure Centre girder:			
(1) Within 0,4L_R amidships	$\omega\sqrt{k_{ms}}\left(0,8\sqrt{L_R}+1,0\right)\geq 4,0\,\omega$	$\omega\sqrt{k_{ms}}\left(0,8\sqrt{L_R}+1,0\right)\geq 4,0\,\omega$	$\omega\sqrt{k_{ms}}\left(0,8\sqrt{L_R}+1,0\right)\geq 4,0\,\omega$
(2) Outside 0,4L_R amidships	$\omega\sqrt{k_{ms}}\left(0,7\sqrt{L_R}+1,0\right)\geq 4,0\,\omega$	$\omega\sqrt{k_{ms}}\left(0,7\sqrt{L_R}+1,0\right)\geq 4,0\,\omega$	$\omega\sqrt{k_{ms}}\left(0,7\sqrt{L_R}+1,0\right)\geq 4,0\,\omega$
Floors and side girders	$\omega\sqrt{k_{ms}}\left(0,6\sqrt{L_R}+0,8\right)\geq 3,5\,\omega$	$\omega\sqrt{k_{ms}}\left(0,6\sqrt{L_R}+0,8\right)\geq 3,5\,\omega$	$\omega\sqrt{k_{ms}}\left(0,6\sqrt{L_R}+0,8\right)\geq 3,5\,\omega$
Inner bottom plating	$\omega\sqrt{k_{ms}}\left(0,5\sqrt{L_R}+1,0\right)\geq 2,5\,\omega$	$\omega\sqrt{k_{ms}}\left(0,5\sqrt{L_R}+1,0\right)\geq 2,5\,\omega$	$\omega\sqrt{k_{ms}}\left(0,5\sqrt{L_R}+1,0\right)\geq 2,5\,\omega$
Bulkheads Watertight bulkhead plating	$\omega\sqrt{k_{ms}}\left(0,33\sqrt{L_R}+1,0\right)\geq 2,5\,\omega$	$\omega\sqrt{k_{ms}}\left(0,33\sqrt{L_R}+1,0\right)\geq 2,5\,\omega$	$\omega\sqrt{k_{ms}}\left(0,33\sqrt{L_R}+1,0\right)\geq 2,5\,\omega$
Deep tank bulkhead plating	$\omega\sqrt{k_{ms}}\left(0,38\sqrt{L_R}+1,2\right)\geq 3,0\,\omega$	$\omega\sqrt{k_{ms}}\left(0,38\sqrt{L_R}+1,2\right)\geq 3,0\,\omega$	$\omega\sqrt{k_{ms}}\left(0,38\sqrt{L_R}+1,2\right)\geq 3,0\,\omega$
Deck plating and stiffeners Strength/Main deck plating	$\omega\sqrt{k_{ms}}\left(0,38\sqrt{L_R}+1,2\right)\geq 3,0\,\omega$	$\omega\sqrt{k_{ms}}\left(0,38\sqrt{L_R}+1,2\right)\geq 3,0\,\omega$	$\omega\sqrt{k_{ms}}\left(0,38\sqrt{L_R}+1,2\right)\geq 3,0\,\omega$
Lower deck/Inside deckhouse	$\omega\sqrt{k_{ms}}\left(0,18\sqrt{L_R}+1,7\right)\geq 2,0\,\omega$	$\omega\sqrt{k_{ms}}\left(0,18\sqrt{L_R}+1,7\right)\geq 2,0\,\omega$	$\omega\sqrt{k_{ms}}\left(0,18\sqrt{L_R}+1,7\right)\geq 2,0\,\omega$
Superstructures and deckhouses Superstructure side plating	$\omega\sqrt{k_{ms}}\left(0,3\sqrt{L_R}+1,0\right)\geq 2,0\,\omega$	$\omega\sqrt{k_{ms}}\left(0,3\sqrt{L_R}+1,0\right)\geq 2,0\,\omega$	$\omega\sqrt{k_{ms}}\left(0,3\sqrt{L_R}+1,0\right)\geq 2,0\,\omega$
Deckhouse front 1st tier	$\omega\sqrt{k_{ms}}\left(0,47\sqrt{L_R}+1,5\right)\geq 3,0\,\omega$	$\omega\sqrt{k_{ms}}\left(0,47\sqrt{L_R}+1,5\right)\geq 3,0\,\omega$	$\omega\sqrt{k_{ms}}\left(0,47\sqrt{L_R}+1,5\right)\geq 3,0\,\omega$
Deckhouse front upper tiers	$\omega\sqrt{k_{ms}}\left(0,42\sqrt{L_R}+1,3\right)\geq 3,0\,\omega$	$\omega\sqrt{k_{ms}}\left(0,42\sqrt{L_R}+1,3\right)\geq 3,0\,\omega$	$\omega\sqrt{k_{ms}}\left(0,42\sqrt{L_R}+1,3\right)\geq 3,0\,\omega$
Deckhouse aft	$\omega\sqrt{k_{ms}}\left(0,2\sqrt{L_R}+0,6\right)\geq 2,0\,\omega$	$\omega\sqrt{k_{ms}}\left(0,2\sqrt{L_R}+0,6\right)\geq 2,0\,\omega$	$\omega\sqrt{k_{ms}}\left(0,2\sqrt{L_R}+0,6\right)\geq 2,0\,\omega$
Pillars Wall thickness of tubular pillars	$\omega\sqrt{k_{ms}}0,05d_p$	$\omega\sqrt{k_{ms}}0,05d_p$	$\omega\sqrt{k_{ms}}0,05d_p$
Wall thickness of rectangular pillars	$\omega\sqrt{k_{ms}}0,05b_p$	$\omega\sqrt{k_{ms}}0,05b_p$	$\omega\sqrt{k_{ms}}0,05b_p$

Symbols
ω = service type factor as determined from *Table 3.2.2 Service type correction factor (ω)* in Chapter 3
k_{ms} = 635/(σ_s + σ_u)
σ_u = specified minimum ultimate tensile strength of the material, in N/mm^2
b_p = minimum breadth of cross-section of hollow rectangular pillar, in mm
d_p = outside diameter of tubular pillar, in mm cross-section
L_R and σ_s are as defined in *Pt 6, Ch 4, 1.5 Symbols and definitions 1.5.1*.

Section 3
Shell envelope plating

3.1 General

3.1.1 Unless otherwise specified within this Section, the scantlings and arrangements for shell envelope plating are to be determined in accordance with the procedures described in, or as required by, *Pt 6, Ch 3, 3 Shell envelope plating* for mono-hull craft using the pressures from *Pt 5 Design and Load Criteria* appropriate to multi-hulls.

3.1.2 The thickness of the shell envelope plating is in no case to be less than the appropriate minimum requirement given in *Pt 6, Ch 4, 2 Minimum thickness requirements*.

3.2 Keel plates

3.2.1 The breadth, b_k, and thickness, t_k, of plate keels are not to be taken as less than:

$$b_k = 5{,}0 L_R + 250 \text{ mm}$$

$$t_k = \sqrt{k_s} 1{,}35 L_R^{0{,}45} \text{ mm}$$

where L_R and k_s are as defined in *Pt 6, Ch 4, 1.5 Symbols and definitions 1.5.1*.

3.2.2 In no case is the thickness of the keel to be less than that of the adjacent bottom shell plating.

3.2.3 The width and thickness of plate keels are to be maintained throughout the length of the craft from the transom to a point not less than 25 per cent of the freeboard (measured at the forward perpendicular) above the deepest load waterline on the stem. Thereafter the keel thickness may be reduced to that required by *Pt 6, Ch 3, 3.3 Plate stem 3.3.1* for the stem.

3.2.4 For large or novel craft and for yachts with externally attached ballast keels, the scantlings of the keel will be specially considered.

3.3 Bottom outboard

3.3.1 The thickness of the bottom outboard plating is to be determined from the general plating equation given in *Pt 6, Ch 3, 1.16 Plating general* using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

3.3.2 For all craft types, the minimum bottom outboard shell thickness requirement given in *Pt 6, Ch 4, 2 Minimum thickness requirements* is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

3.4 Bottom inboard

3.4.1 The thickness of the bottom inboard plating is to be determined from the general plating equation given in *Pt 6, Ch 3, 1.16 Plating general* using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

3.4.2 For all craft types, the minimum bottom inboard shell thickness requirement given in *Pt 6, Ch 4, 2 Minimum thickness requirements* is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

3.5 Side outboard

3.5.1 The thickness of the side outboard plating is to be determined from the general plating equation given in *Pt 6, Ch 3, 1.16 Plating general* using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

3.6 Side inboard

3.6.1 The thickness of the side inboard plating is to be determined from the general plating equation given in *Pt 6, Ch 3, 1.16 Plating general* using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

3.7 Wet-deck

3.7.1 The thickness of the wet-deck plating is to be determined from the general plating equation given in *Pt 6, Ch 3, 1.16 Plating general* using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

3.7.2 Additionally, the thickness of the wet-deck plating is in no case to be less than the thickness of the side inboard shell plating determined from *Pt 6, Ch 4, 3.6 Side inboard*.

3.7.3 The wet-deck plating on the underside of the cross-deck structure may require to be additionally protected, particularly where the air gap is small and there is a high risk of localised impact due to collision with floating debris, ice, etc. in the service area. In such cases the sheathing requirements given in *Pt 6, Ch 3, 2.4 Sheathing* are to be complied with.

3.8 Transom

3.8.1 The scantlings and arrangements of the stern or transom are to be not less than that required for the adjacent bottom inboard or side outboard structure as appropriate. Where water jet or sterndrive units are fitted, the scantlings of the plating in way of the nozzles and connections will be specially considered.

3.9 Haunch reinforcement (SWATH)

3.9.1 For craft above 40 metres in Rule length, L_R, the stresses in the haunch area are to be derived using a two dimensional fine mesh finite element analysis. The model is to extend horizontally into the box structure and vertically into the strut structure. All discontinuities and cut-outs are to be modelled in order to determine shear stresses at critical locations and stresses for the determination of fatigue strength.

3.9.2 Due consideration is to be given to shear lag when determining the effective breadth of the attached plating.

3.10 Lower hull (SWATH)

3.10.1 Where the lower hull structure incorporates ring frames and attached shell plating fitted between bulkheads or diaphragms, the thickness of the lower hull shell plating may be derived from an established method for shell analysis or recognised standard for pressure vessels using the design pressure loading from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* as appropriate. Other loads considered significant for the scantling determination are to be taken into account. Modes of failure to be considered are buckling, frame collapse, inter-frame shell collapse and overall frame shell collapse between bulkheads. A copy of the direct calculations are to be submitted for consideration.

3.11 Novel features

3.11.1 Where the Rules do not specifically define the requirements for plating elements with novel features then the scantlings and arrangements are to be determined by direct calculations. Such calculations are to be carried out on the basis of the Rules, Recognised Standards and good practice, and are to be submitted for consideration.

Section 4
Shell envelope framing

4.1 General

4.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for shell envelope framing are to be determined in accordance with the procedures described in, or as required by, *Pt 6, Ch 3, 3 Shell envelope plating* for mono-hull craft using the pressures from *Pt 3 General Requirements and Constructional Arrangements* appropriate to multi-hulls.

4.1.2 The requirements in this Section apply to longitudinally and transversely framed shell envelopes.

4.2 Bottom outboard longitudinal stiffeners

4.2.1 Bottom outboard longitudinal stiffeners are to be supported by transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.2.2 Bottom outboard longitudinals are to be continuous through the supporting structures.

4.2.3 Where it is impracticable to comply with the requirements of *Pt 6, Ch 4, 4.2 Bottom outboard longitudinal stiffeners 4.2.2*, or where it is proposed to terminate the bottom outboard longitudinals in way of the transom, bulkheads or integral tank boundaries, all longitudinals are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets.

4.2.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 6, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* in Chapter 3 for the load model (b).

4.3 Bottom outboard longitudinal primary stiffeners

4.3.1 Bottom outboard longitudinal primary stiffeners are to be supported by deep transverse web frames, floors, bulkheads, or other primary structures, generally spaced not more than 4 m apart.

4.3.2 Bottom outboard longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

4.3.3 Where it is impracticable to comply with the requirements of *Pt 6, Ch 4, 4.3 Bottom outboard longitudinal primary stiffeners 4.3.2*, or where it is proposed to terminate the stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be `soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.3.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 6, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* in Chapter 3 for the load model (a).

4.4 Bottom outboard transverse stiffeners

4.4.1 Bottom outboard transverse stiffeners are defined as local stiffening members which support the bottom shell and which may be continuous or intercostal.

4.4.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 6, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* in Chapter 3 for the load model (b).

4.5 Bottom outboard transverse frames

4.5.1 Bottom outboard transverse frames are defined as stiffening members which support the bottom shell. They are to be effectively continuous and bracketed at their end connections to side frames and bottom floors as appropriate.

4.5.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 6, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* in Chapter 3 for the load model (a).

4.6 Bottom outboard transverse web frames

4.6.1 Bottom outboard transverse web frames are defined as primary stiffening members which support bottom shell longitudinals. They are to be continuous and substantially bracketed at their end connections to side web frames and bottom floors.

4.6.2 Where it is impracticable to comply with the requirements of *Pt 6, Ch 4, 4.6 Bottom outboard transverse web frames 4.6.1*, or where it is proposed to terminate the web frames in way of bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets. All brackets are to be `soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.6.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 6, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* in Chapter 3 for the load model (a).

4.7 Bottom inboard longitudinal stiffeners

4.7.1 The scantlings and arrangements for bottom inboard longitudinal stiffeners are to be determined in accordance with the procedures described in *Pt 6, Ch 4, 4.2 Bottom outboard longitudinal stiffeners* using the bottom inboard stiffening member design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

4.8 Bottom inboard longitudinal primary stiffeners

4.8.1 The scantlings and arrangements for bottom inboard longitudinal primary stiffeners are to be determined in accordance with the procedures described in *Pt 6, Ch 4, 4.3 Bottom outboard longitudinal primary stiffeners* using the bottom inboard stiffening member design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

4.9 Bottom inboard transverse stiffeners

4.9.1 The scantlings and arrangements for bottom inboard transverse stiffeners are to be determined in accordance with the procedures described in *Pt 6, Ch 4, 4.4 Bottom outboard transverse stiffeners* using the bottom inboard stiffening member design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

4.10 Bottom inboard transverse frames

4.10.1 The scantlings and arrangements for bottom inboard transverse frames are to be determined in accordance with the procedures described in *Pt 6, Ch 4, 4.5 Bottom outboard transverse frames* using the bottom inboard stiffening member design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

4.11 Bottom inboard transverse web frames

4.11.1 The scantlings and arrangements for bottom inboard transverse frames are to be determined in accordance with the procedures described in *Pt 6, Ch 4, 4.6 Bottom outboard transverse web frames* using the bottom inboard stiffening design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

4.12 Side outboard longitudinal stiffeners

4.12.1 The side outboard longitudinal stiffeners are to be supported by transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.12.2 Side outboard longitudinals are to be continuous through the supporting structures.

4.12.3 Where it is impracticable to comply with the requirements of *Pt 6, Ch 4, 4.12 Side outboard longitudinal stiffeners 4.12.2*, or where it is proposed to terminate the side outboard longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets.

4.12.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 6, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients*in Chapter 3 for the load model (b).

4.13 Side outboard longitudinal primary stiffeners

4.13.1 Side outboard longitudinal primary stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 4 m apart.

4.13.2 Side outboard longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

4.13.3 Where it is impracticable to comply with the requirements of *Pt 6, Ch 4, 4.13 Side outboard longitudinal primary stiffeners 4.13.2*, or where it is proposed to terminate the side outboard longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be `soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.13.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 6, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients*in Chapter 3 for the load model (a).

4.14 Side outboard transverse stiffeners

4.14.1 Side outboard transverse stiffeners are defined as local stiffening members supporting the side shell and may be continuous or intercostal.

4.14.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 6, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* in Chapter 3 for the load model (b).

4.15 Side outboard transverse frames

4.15.1 Side outboard transverse frames are defined as stiffening members supporting the side shell and spanning continuously between bottom floors/frames and decks. They are to be effectively constrained against rotation at their end connections.

4.15.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 6, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* in Chapter 3 for the load model (a).

4.16 Side outboard transverse web frames

4.16.1 Side outboard transverse web frames are defined as primary stiffening members which support side shell longitudinals. They are to be continuous and substantially bracketed at their head and heel connections to deck beams and bottom web frames respectively.

4.16.2 Where it is impracticable to comply with the requirements of *Pt 6, Ch 4, 4.16 Side outboard transverse web frames 4.16.1*, or where it is proposed to terminate the side outboard longitudinals in way of bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be `soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.16.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 6, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* in Chapter 3 for the load model (a).

4.17 Side inboard longitudinal stiffeners

4.17.1 The scantlings and arrangements for side inboard longitudinal stiffeners are to be determined in accordance with the procedures described in *Pt 6, Ch 4, 4.12 Side outboard longitudinal stiffeners* using the side inboard design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

4.18 Side inboard longitudinal primary stiffeners

4.18.1 The scantlings and arrangements for side inboard longitudinal primary stiffeners are to be determined in accordance with the procedures described in *Pt 6, Ch 4, 4.13 Side outboard longitudinal primary stiffeners* using the side inboard design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

4.19 Side inboard transverse stiffeners

4.19.1 The scantlings and arrangements for side inboard transverse stiffeners are to be determined in accordance with the procedures described in *Pt 6, Ch 4, 4.14 Side outboard transverse stiffeners* using the side inboard design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

4.20 Side inboard transverse frames

4.20.1 The scantlings and arrangements for side inboard transverse frames are to be determined in accordance with the procedures described in *Pt 6, Ch 4, 4.15 Side outboard transverse frames* using the side inboard design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

4.21 Side inboard transverse web frames

4.21.1 The scantlings and arrangements for side inboard transverse frames are to be determined in accordance with the procedures described in *Pt 6, Ch 4, 4.16 Side outboard transverse web frames* using the side inboard design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

4.22 Wet-deck longitudinal stiffeners

4.22.1 The wet-deck longitudinal stiffeners are to be supported by transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.22.2 Wet-deck longitudinals are to be continuous through the supporting structures.

4.22.3 Where it is impracticable to comply with the requirements of *Pt 6, Ch 4, 4.22 Wet-deck longitudinal stiffeners 4.22.2*, or where it is proposed to terminate the wet-deck longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.22.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 6, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* in Chapter 3 for the load model (b).

4.22.5 In no case are the scantlings and arrangements for the wet-deck longitudinal stiffeners to be taken as less than those required for the side inboard longitudinal stiffeners detailed in *Pt 6, Ch 4, 4.17 Side inboard longitudinal stiffeners*.

4.23 Wet-deck longitudinal primary stiffeners

4.23.1 Wet-deck longitudinal primary stiffeners are to be supported by transverse web frames, bulkheads, or other primary structure, generally spaced not more than 4 m apart.

4.23.2 Wet-deck longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

4.23.3 Where it is impracticable to comply with the requirements of *Pt 6, Ch 4, 4.23 Wet-deck longitudinal primary stiffeners 4.23.2*, or where it is proposed to terminate the wet-deck longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be `soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.23.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 6, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* in Chapter 3 for the load model (a).

4.23.5 In no case are the scantlings and arrangements for the wet-deck longitudinal primary stiffeners to be taken as less than those required for the side inboard longitudinal primary stiffeners detailed in *Pt 6, Ch 4, 4.18 Side inboard longitudinal primary stiffeners*.

4.23.6 Additionally the requirements of *Pt 6, Ch 6 Hull Girder Strength* relating to global strength are to be complied with.

4.24 Wet-deck transverse stiffeners

4.24.1 Wet-deck transverse stiffeners are defined as local stiffening members supporting the wet-deck and may be continuous or intercostal.

4.24.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 6, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* in Chapter 3 for the load model (b).

4.24.3 In no case are the scantlings and arrangements for the wet-deck transverse stiffeners to be taken as less than those required for the side inboard transverse stiffeners detailed in *Pt 6, Ch 4, 4.19 Side inboard transverse stiffeners*.

4.25 Wet-deck transverse frames

4.25.1 Wet-deck transverse frames are defined as stiffening members which support the wet-deck. They are to be effectively continuous and bracketed at their end connections to side frames.

4.25.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 6, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* in Chapter 3 for the load model (a).

4.25.3 In no case are the scantlings and arrangements for the `wet-deck' transverse frames to be taken as less than those required for the side inboard transverse frames detailed in *Pt 6, Ch 4, 4.20 Side inboard transverse frames*.

4.26 Wet-deck transverse web frames

4.26.1 Wet-deck transverse web frames are defined as primary stiffening members which support wet-deck longitudinals. They are to be continuous and substantially bracketed at their end connections to side transverse web frames.

4.26.2 Where it is impracticable to comply with the requirements of *Pt 6, Ch 4, 4.26 Wet-deck transverse web frames 4.26.1*, or where it is proposed to terminate the wet-deck longitudinals in way of the bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be `soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.26.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 6, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* in Chapter 3 for the load model (a).

4.26.4 In no case are the scantlings and arrangements for the wet-deck transverse web frames to be taken as less than those required for the side inboard transverse web frames detailed in *Pt 6, Ch 4, 4.21 Side inboard transverse web frames*.

4.26.5 Primary transverse web frames that link the strength deck to the wet-deck structure and which carry the transverse global loading are additionally to comply with *Pt 6, Ch 6, 3.4 Torsional strength*.

4.26.6 Particular attention is to be taken to ensure that the continuity of transverse structural strength is maintained. All primary transverse members are to be continuous through the inboard side structure and integrated into transverse bulkheads or other primary structure within each hull (*see Figure 4.4.1 End connection details, wet-deck structure*). In the case of trimaran type craft the primary transverse members are to be continuous through the centre hull. Additionally the side inboard shell plating in way of the intersection is to be increased locally by not less than 50 per cent.

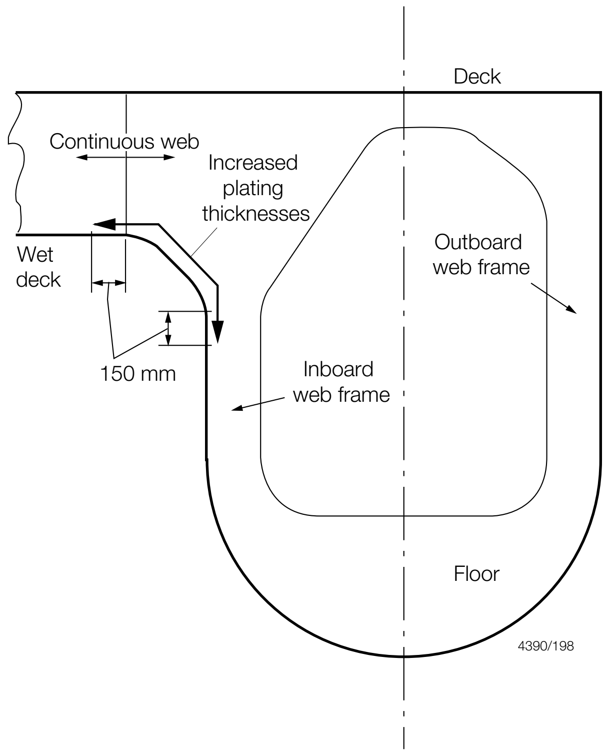


Figure 4.4.1 End connection details, wet-deck structure

4.27 Lower hull (SWATH)

4.27.1 Where the lower hull structure incorporates ring frames and attached shell plating fitted between bulkheads or diaphragms, the scantlings of the lower hull shell stiffening may be derived from an established method for stiffening analysis or Recognised Standard for pressure vessels using the design loading from *Pt 5, Ch 4, 3.1 Hull structures* Modes of failure to be considered are buckling, frame collapse, inter frame shell collapse and overall frame shell collapse between bulkheads. A copy of the direct calculations is to be submitted for consideration.

4.28 Scantlings of end brackets

4.28.1 The scantlings of end brackets in way of transverse web frames/crossdeck primary structure which carry transverse global loading, are to be as large as practicable and be additionally reinforced as necessary. The webs of deep brackets are to be stiffened as necessary to resist buckling, *see also Pt 6, Ch 6, 3.5 Strength of cross-deck structures*.

Section 5
Single bottom structure and appendages

5.1 General

5.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for single bottom structure and appendages are to be determined in accordance with the procedures described in, or as required by, *Pt 6, Ch 3, 5 Single bottom structure and appendages* for mono-hull craft using the pressures from *Pt 5 Design and Load Criteria* appropriate to multi-hulls.

5.1.2 The thickness of single bottom structural members is in no case to be less than the appropriate minimum requirement given in *Pt 6, Ch 4, 2 Minimum thickness requirements*.

5.2 Keel

5.2.1 The scantlings and arrangements of plate keels are to be in accordance with *Pt 6, Ch 4, 3.2 Keel plates*.

5.2.2 Where fitted, the cross-sectional area, A_{bk}, and thickness, t_{bk}, of bar keels are not, in general, be taken as less than:

$$A_{\text{bk}} = 0,75 L_{\text{R}} k_{\text{s}} \text{ cm}^2$$

$$t_{\text{bk}} = \sqrt{k_{\text{s}}}\left(0,5 L_{\text{R}} + 2\right) \text{ mm}$$

where L_{R} and k_{s} are as defined in *Pt 6, Ch 4, 1.5 Symbols and definitions 1.5.1*.

5.3 Centre girder

5.3.1 Centreline girders are to be fitted throughout the length of each hull and are generally to be fitted in association with transverse frames, transverses supporting longitudinals or where the breadth of floors at the upper edge is greater than 1,5 m.

5.3.2 Centreline girders may be formed with intercostal or continuous plate webs. In all cases the face flat is to be continuous. Where girder webs are intercostal, additional bracketing and local reinforcement are to be provided to maintain the continuity of structural strength.

5.3.3 The web depth of the centre girder is, in general, to be equal to the depth of the floors at the centreline as specified in *Pt 6, Ch 4, 5.5 Floors 5.5.3*.

5.3.4 The web thickness, t_{w}, of the centre girder is to be taken not less than:

$$t_w = \sqrt{k_{\text{s}}}\left(0,8\ L_{\text{R}} + 1\right) \text{ mm}$$

where L_{R} and k_{s} are as defined in *Pt 6, Ch 4, 1.5 Symbols and definitions 1.5.1*.

5.3.5 The face flat area, A_{f}, of the centre girder is to be not less than:

$$A_{\text{f}} = k_{\text{s}} 0,22 L_{\text{R}} \text{ cm}^2$$

where L_{R} and k_{s} are as defined in *Pt 6, Ch 4, 1.5 Symbols and definitions 1.5.1*.

5.3.6 The geometric section properties of the centre girder are to be in accordance with *Pt 6, Ch 3, 1.18 Geometric properties and proportions of stiffener sections*.

5.3.7 The face flat area of the centre girder outside $0,5L_{\text{R}}$ may be 80 per cent of the value given in *Pt 6, Ch 4, 5.3 Centre girder 5.3.5*.

5.3.8 The face flat thickness is to be not less than the thickness of the web, t_{w}, as determined from *Pt 6, Ch 4, 5.3 Centre girder 5.3.4*.

5.3.9 The ratio of the width to thickness of the face flat is to be not less than eight but is not to exceed 16.

5.3.10 Additionally, the requirements of *Pt 6, Ch 4, 4.8 Bottom inboard longitudinal primary stiffeners* for bottom inboard longitudinal primary stiffeners are to be complied with.

5.4 Side girders

5.4.1 Where the floor breadth at the upper edge exceeds 4,0 m, side girders are to be fitted at each side of the centre girder such that the spacing between the side and centre girders or between the side girders themselves is not greater than 2 metres. Side girders where fitted are to extend as far forward and aft as practicable and are, in general, to be scarfed into the bottom structure forward and aft of the support at which they terminate, i.e. in way of bulkheads, deep floors or other primary transverse structure.

5.4.2 The web thickness, t_w, of side girder webs is to be taken as not less than:

$$t_w = \sqrt{\left(0,43 k_s L_R\right)} \text{ mm}$$

where L_R and k_s are as defined in *Pt 6, Ch 4, 1.5 Symbols and definitions 1.5.1*.

5.4.3 The face flat area and thickness of side girders are to comply with the requirements for plate floors as defined in *Pt 6, Ch 4, 5.5 Floors 5.5.6* and *Pt 6, Ch 4, 5.5 Floors 5.5.7*.

5.4.4 Additionally, the requirements of *Pt 6, Ch 4, 4.8 Bottom inboard longitudinal primary stiffeners* for bottom inboard longitudinal primary stiffeners are to be complied with.

5.4.5 Watertight side girders and side girders forming the boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads and deep tanks as detailed in *Pt 6, Ch 3, 7.2 Watertight bulkhead plating* and *Pt 6, Ch 3, 7.4 Deep tank plating* respectively.

5.4.6 In the engineroom, additional side girders are generally to be fitted in way of main machinery seatings. Where fitted they are to be integrated into the structure of the craft and extended forward and aft as far as practicable.

5.5 Floors

5.5.1 In transversely framed craft, floors are generally to be fitted at every frame and underneath each bulkhead.

5.5.2 In longitudinally framed craft, floors are in general to be fitted at every transverse web frame and bulkhead and generally at a spacing not exceeding 2 m. Additional transverse floors or webs are to be fitted at half web-frame spacing in way of engine seatings and thrust bearings, pillars, skegs, ballast/bilge keels and the bottom of the craft in the forefoot region.

5.5.3 The overall depth, d_f, of floors at the centreline, is not to be taken as less than:

$$d_f = 6,2 L_R + 50 \text{ mm}$$

where L_R is as defined in *Pt 6, Ch 4, 1.5 Symbols and definitions 1.5.1*.

5.5.4 The web thickness of plate floors, t_w, is to be in accordance with *Pt 6, Ch 3, 1.18 Geometric properties and proportions of stiffener sections* and not less than:

$$t_w = \sqrt{k_s}\left(\frac{3,4 d_f}{1000} + 2,25\right)\left(\frac{s}{1000} + 0,5\right) \text{ mm}$$

where

d_f is to be determined from *Pt 6, Ch 4, 5.5 Floors 5.5.3*

k_s and s are as defined in *Pt 6, Ch 4, 1.5 Symbols and definitions 1.5.1*.

5.5.5 If the side frames of the craft are attached to the floors by brackets, the depth of floor may be reduced by 15 per cent and the floor thickness determined using the reduced depth. The brackets are to be flanged and have the same thickness as the floors, and their arm lengths clear of the frame are to be the same as the reduced floor depth given above.

5.5.6 The face flat area, A_f, of floors is not to be taken as less than:

$$A_f = 0,11 k_s L_R \text{cm}^2$$

where k_s and L_R are as defined in *Pt 6, Ch 4, 1.5 Symbols and definitions 1.5.1*.

5.5.7 The face flat thickness, t_f, is to be not less than the thickness of the web and the ratio of the web to the thickness of the face flat is to be not less than eight but is not to exceed 16.

5.5.8 Additionally, the requirements of *Pt 6, Ch 4, 4.11 Bottom inboard transverse web frames* for bottom inboard transverse web frames are to be complied with.

5.5.9 Floors are in general to be continuous from side to side.

5.5.10 The tops of floors, in general, may be level from side to side. However, in craft having considerable rise of floor the depth of the floor plate may require to be increased to maintain the required section modulus.

5.5.11 The floors in the aft peak are to extend over and provide efficient support to the sterntube(s) where applicable.

5.5.12 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deep tanks as detailed in *Pt 6, Ch 3, 7.3 Watertight bulkhead stiffening* and *Pt 6, Ch 3, 7.5 Deep tank stiffening*.

5.6 Floors in machinery space

5.6.1 The web thickness, t_w, of floors in machinery spaces is to be 1 mm greater than that required by *Pt 6, Ch 4, 5.5 Floors 5.5.4*.

5.6.2 The depth and mechanical strength properties of floors between engine or gearbox girders is to be not less than that required to maintain continuity of structural integrity or 50 per cent of the depth given in *Pt 6, Ch 4, 5.5 Floors 5.5.3*. The face flat area and web thickness of such reduced height floors are to be increased appropriately in order to maintain the continuity of structural strength, *see also Pt 6, Ch 3, 4.12 Grouped frames*.

5.7 Forefoot and stem

5.7.1 The thickness of plate stems at the waterline is to comply with the requirements for plate keels as given in *Pt 6, Ch 4, 3.2 Keel plates*.

5.7.2 The forefoot and stem is to be additionally reinforced with floors.

5.7.3 The cross-sectional area of bar stems, A_{bs}, is not to be taken as less than:

$$A_{bs} = 0,6 k_s L_R \text{ cm}^2$$

where

k_s and L_R are as defined in *Pt 6, Ch 4, 1.5 Symbols and definitions 1.5.1*.

■ Section 6 Double bottom structure

6.1 General

6.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for the double bottom structure are to be determined in accordance with the procedures described in, or as required by, *Pt 6, Ch 3, 6 Double bottom structure* for mono-hull craft using the pressures from *Pt 5 Design and Load Criteria* appropriate to multi-hulls.

6.1.2 The thickness of double bottom structural members is in no case to be less than the appropriate minimum requirement given in *Pt 6, Ch 4, 2 Minimum thickness requirements*.

6.2 Keel

6.2.1 The scantlings of plate and bar keels are to comply with the requirements of *Pt 6, Ch 4, 5.2 Keel*.

6.3 Centreline girder

6.3.1 A centre girder is to be fitted throughout the length of the craft. The web thickness, t_w, is not to be less than that required by:

$$t_w = \sqrt{k_s}\left(0,06 L_R + 3\right) \text{ mm within } 0{,}4 L_R \text{ amidships}$$

$$t_w = \sqrt{k_s}\left(0{,}6 L_R + 2\right) \text{ mm at the ends}$$

where k_s and L_R are as defined in *Pt 6, Ch 4, 1.5 Symbols and definitions 1.5.1*.

6.3.2 The geometric properties of the girder section are to be in accordance with *Pt 6, Ch 3, 1.18 Geometric properties and proportions of stiffener sections*.

6.3.3 The overall web depth, d_w, of the centre girder is to be taken as not less than 630 mm and is to be sufficient to give adequate access to all parts of the double bottom.

6.3.4 Additionally, the requirements of *Pt 6, Ch 4, 4.8 Bottom inboard longitudinal primary stiffeners* for bottom inboard longitudinal primary stiffeners are to be complied with.

6.4 Side girders

6.4.1 Where the floor breadth does not exceed 4,0 m, side girders are not required. Vertical stiffeners are to be fitted to the floors on each side, the number and positions of these stiffeners being dependent on the arrangement of the double bottom structure.

6.4.2 Where the breadth of floor is greater than 4,0 m, additional side girders having the same thickness as the floors are to be fitted. The number of side girders is to be such that the distance between the side girders and centre girder and margin plate, or between the side girders themselves, does not exceed 2,0 m.

6.4.3 Side girders, where fitted, are to extend as far forward and aft as practicable and are in general to to be scarfed into the bottom structure forward and aft of the supporting bulkheads, deep floors or other primary transverse structure

6.4.4 Where additional side girders are fitted in way of main machinery seatings, they are to be integrated into the structure of the craft and extended forward and aft as far as practicable.

6.4.5 Under the main engine, girders extending from the bottom shell to the top plate of the engine seating are to be fitted. The height of the girders is to be not less than the height of the floor. Engine holding-down bolts are to be arranged as near as practicable to the girders and floors. Where this cannot be achieved, bracket floors and/or hanging brackets are to be fitted.

6.4.6 The geometric properties of the girder section are to be in accordance with *Pt 6, Ch 3, 1.18 Geometric properties and proportions of stiffener sections*.

6.4.7 Additionally, the requirements of *Pt 6, Ch 4, 4.3 Bottom outboard longitudinal primary stiffeners* for bottom inboard longitudinal primary stiffeners are to be complied with.

6.5 Plate floors

6.5.1 The web thickness, t_w, of non-watertight plate floors is to be not less than:

$$t_w = \sqrt{k_s}\left(0,03L_R + 3,5\right) \text{ mm}$$

where k_s and L_R are as defined in *Pt 6, Ch 4, 1.5 Symbols and definitions 1.5.1*.

6.5.2 The geometric properties of the floor section are to be in accordance with *Pt 6, Ch 3, 1.18 Geometric properties and proportions of stiffener sections*.

6.5.3 Additionally, the requirements of *Pt 6, Ch 4, 4.6 Bottom outboard transverse web frames* for bottom inboard transverse web frames are to be complied with.

6.5.4 Plate floors are, in general, to be continuous between the centre girder and the margin plate.

6.5.5 In longitudinally framed craft, plate floors are to be fitted in the following positions:

(a) At every half frame in way of the main engines, thrust bearings, and bottom of the craft forward.
(b) Outboard of the engine seatings, at every frame within the engineroom.
(c) Underneath pillars and bulkheads.
(d) Outside of the engine room at a spacing not exceeding 2,0 m.

6.5.6 Vertical flat bar stiffeners are to be fitted to all plate floors at each longitudinal. Each stiffener is to have a depth of not less than $10t_w$ and a thickness of not less than t_w, where t_w is thickness of the plate floor as calculated in *Pt 6, Ch 4, 6.5 Plate floors 6.5.1*.

6.5.7 In transversely framed craft, plate floors are to be fitted at every frame in the engineroom, under bulkheads, in way of change in depth of double bottom and elsewhere at a spacing not exceeding 2,0 m.

6.6 Additional requirements for watertight floors

6.6.1 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deeptanks as detailed in *Pt 6, Ch 3, 7.2 Watertight bulkhead plating* or *Pt 6, Ch 3, 7.4 Deep tank plating* respectively.

■ *Section 7* Bulkheads and deep tanks

7.1 General

7.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for bulkheads and deep tanks are to be determined in accordance with the procedures described in, or as required by *Pt 7, Ch 3, 7 Bulkheads and deep tanks* for mono-hull craft using the pressures from *Pt 5 Design and Load Criteria* appropriate to multi-hulls.

7.2 Longitudinal bulkheads within the cross-deck structure

7.2.1 Longitudinal bulkheads are to be fitted within the cross-deck structure to prevent cross flooding and the spread of flame and smoke. The minimum number of such bulkheads is to be:

- one for catamarans of Rule length, L_R, less than or equal to 24 m;
- two for catamarans of Rule length, L_R, greater than 24 m; and
- four for trimarans.

Quadrimarans and other craft of novel configuration will be specially considered.

7.2.2 The scantlings and arrangements for cross-deck longitudinal bulkheads are to be determined in accordance with the procedures described in *Pt 6, Ch 3, 7.2 Watertight bulkhead plating* and *Pt 6, Ch 3, 7.3 Watertight bulkhead stiffening* for bulkheads in mono-hull craft.

7.2.3 In addition the requirements of *Pt 6, Ch 4, 7.4 Additional strength required for global loading* with regard to global strength are to be complied with.

7.3 Transverse bulkheads within the cross-deck structure

7.3.1 The scantlings of cross-deck transverse bulkheads are to be determined in accordance with the procedures described in *Pt 6, Ch 3, 7.2 Watertight bulkhead plating* and *Pt 6, Ch 3, 7.3 Watertight bulkhead stiffening* for bulkheads in mono-hull craft.

7.3.2 In addition the requirements of *Pt 6, Ch 4, 7.4 Additional strength required for global loading* in respect of global strength are to be complied with.

7.4 Additional strength required for global loading

7.4.1 Where transverse bulkheads or deep tank bulkheads within the cross-deck structure are to assist in resisting torsional or bending loads between the hulls, then the watertight/deep tank bulkheads may be required to be additionally stiffened and the plating or skin thicknesses may require to be increased. For hull girder strength requirements, *see Pt 6, Ch 6, 3 Additional hull girder strength requirements for multi-hull craft*.

7.4.2 Longitudinal bulkheads within the cross-deck structure that are to assist in maintaining the longitudinal strength of the craft are to satisfy both bulkhead/deep tank and longitudinal strength requirements. This may require additional stiffening and increase in plate thickness requirements. For hull girder strength requirements, *see Pt 6, Ch 6, 3 Additional hull girder strength requirements for multi-hull craft*.

7.4.3 Where longitudinal or transverse cross-deck bulkheads/deep tanks are to carry global loads, detailed calculations are to be submitted.

7.4.4 For longitudinal or transverse cross-deck members carrying global loads, consideration is to be given to stiffener arrangement, alignment, and continuity in order to maximise the rigidity and stiffness of the structure, in resisting the torsional/bending loads. Discontinuity of structural bulkheads is to be avoided.

7.5 Access

7.5.1 Access through the cross-deck structure may be permitted, provided that the global strength requirements are satisfied. Cut outs through the bulkhead are not to exceed 50 per cent of its depth, *see also Pt 6, Ch 3, 7.18 Access*

7.5.2 Where the cross-deck structure acts as a watertight bulkhead pipe or cable runs through the watertight bulkheads are to be fitted with suitable watertight glands.

7.6 Local reinforcement

7.6.1 Bulkheads forming the cross-deck structure are to be suitably strengthened, if necessary, in way of deck girders and where subjected to concentrated loads.

7.7 Integral/Deep tanks within cross-deck structure

7.7.1 Where the cross-deck structure forms the boundaries of deep tanks, the scantlings of these boundaries are to satisfy both deep tank and global strength requirements. For general and structural requirements for deep tanks, *see Pt 6, Ch 3, 7 Bulkheads and deep tanks*. For global considerations of strength, *see Pt 6, Ch 6, 3 Additional hull girder strength requirements for multi-hull craft*.

■ *Section 8* Deck structures

8.1 General

8.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for deck structures are to be determined in accordance with the procedures described in, or as required by, *Pt 6, Ch 3, 8 Deck structures* for mono-hull craft using the pressures from *Pt 5 Design and Load Criteria* appropriate to multi-hulls.

8.2 Arrangements

8.2.1 Design loads to be applied for cross-deck scantling calculations are transverse vertical bending moment and shear force, twin hull torsional connecting moment, external pressure load and appropriate internal loads as defined in *Pt 3 General Requirements and Constructional Arrangements*.

8.2.2 For craft up to 50 m in Rule length, L_R, where the cross-deck is formed by transverse primary stiffeners or bulkheads, and subjected to global transverse loads in accordance with *Pt 6, Ch 4, 8.2 Arrangements 8.2.1* the scantling requirements to satisfy the global loading condition are given in *Pt 6, Ch 6, 3.5 Strength of cross-deck structures*.

8.2.3 Superstructures fitted on the cross-deck structures, on craft up to 50 m in Rule length, L_R, will, in general, be considered as non load carrying and are not to be included in the strength of the cross-deck. For designs where the superstructure is designed to absorb global loads, the requirements are given in *Pt 6, Ch 6, 3.2 Hull longitudinal bending strength*.

8.2.4 For craft more than 50 m in Rule length, L_R, global analysis is required to determine the response of the deck and superstructure as a system. Deck scantlings may then be derived for compliance with the requirements of *Pt 6, Ch 6, 3 Additional hull girder strength requirements for multi-hull craft*.

8.3 Cross-deck plating

8.3.1 The thickness of the cross-deck plating is to be determined from the general plating equation given in *Pt 6, Ch 3, 1.16 Plating general* using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

8.3.2 The thickness of the cross-deck plating is in no case to be less than the appropriate minimum requirement given in *Pt 6, Ch 4, 2 Minimum thickness requirements*.

8.3.3 The scantlings of watertight cockpits are to be of equivalent strength to those of the strength/weather deck, *see also Pt 4 Additional Requirements for Yachts*.

8.3.4 It is recommended that the working areas of the weather deck have an anti-slip surface.

8.3.5 Where decks are sheathed with wood or other materials, details of the method of attachment are to be submitted, *see also Pt 6, Ch 3, 2.4 Sheathing*.

8.4 Cross-deck stiffening

8.4.1 The Rule requirements for section modulus, inertia and web area for the cross-deck primary stiffeners are to be determined from the general equations given in *Pt 6, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (a).

8.4.2 The Rule requirements for section modulus, inertia and web area of the strength/weather deck secondary stiffening are to be determined from the general equations given in *Pt 6, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.4.3 The geometric properties of stiffener sections are to be in accordance with *Pt 6, Ch 3, 1.18 Geometric properties and proportions of stiffener sections*.

8.4.4 For cases where there may be excessive rotations or deflections at supports or where the lateral pressure distribution is non-uniform, the above scantlings may require increasing appropriately.

8.4.5 Where stiffeners are subject to concentrated loads such as pillars, the concentrated loads are to be superimposed on the lateral pressure and strength calculations carried out to demonstrate compliance with the deflection and stress criteria given in *Pt 6, Ch 7, 2 Deflection control* and *Pt 6, Ch 7, 3 Stress control*.

8.4.6 Where stiffening members support plating of the extruded plank type, or the floating frame system is used, the plating is not to be included in the scantling derivation of the supporting structure.

8.4.7 Openings in the cross-deck for hatches etc. are to comply with the requirements of *Pt 6, Ch 3, 8.11 Deck openings*.

8.5 Novel features

8.5.1 Where the cross-deck structure is of unusual design, form or proportions, the scantlings are to be determined by direct calculation and a copy submitted for consideration.

■ *Section 9*
Superstructures, deckhouses, pillars and bulwarks

9.1 General

9.1.1 The scantlings and arrangements for superstructures, deckhouses and bulwarks are to be determined in accordance with the procedures described in, or as required by, *Pt 6, Ch 3, 9 Superstructures, deckhouses and bulwarks* for mono-hull craft.

9.1.2 The scantlings and arrangements for pillars and pillar bulkheads are to be determined in accordance with the procedures described in, or as required by, *Pt 6, Ch 3, 10 Pillars and pillar bulkheads* for mono-hull craft.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull and multi-hull craft of steel construction as defined in *Ch 1, 1 Background*.

1.2 Symbols and definitions

1.2.1 The symbols and definitions used in this Chapter are defined below and in the appropriate Section:

s = secondary stiffener spacing, in mm

k_S = higher tensile steel factor, as defined in *Pt 6, Ch 2, 2.4 Mechanical properties for design*

σ_S = specified minimum yield strength of the material, in N/mm^2.

■ *Section 2* Special features

2.1 Water jet propulsion systems - Construction

2.1.1 The requirements for the construction and installation of water jet units apply irrespective of rated power.

2.1.2 Water jet ducts may be fabricated as an integral part of the hull structure, or as a bolted-in unit. In either case, detailed plans indicating dimensions, scantlings and materials of construction of the following are to be submitted in triplicate:

(a) Arrangement of the system including intended method of attachment to the hull and building-in, geometry of tunnel, shell opening, method of stiffening, reinforcement, etc.
(b) Shaft sealing arrangements.
(c) Details of any shafting support or guide vanes used in the water jet system.
(d) Details and arrangements of inspection ports, their closing appliances and sealing arrangement, etc.
(e) Details and arrangements of protection gratings and their attachments.

2.1.3 When submitting the plans requested in *Pt 6, Ch 5, 2.1 Water jet propulsion systems - Construction 2.1.2*, details of the designers' loadings and their positions of application in the hull are to be submitted. These are to include maximum applied thrust, moments and tunnel pressures for which approval is sought.

2.1.4 All materials used in construction are to be manufactured and tested in accordance with the *Rules for the Manufacture, Testing and Certification of Materials, July 2021*.

2.1.5 Steels are to be of suitable grades in accordance with the requirements of *Pt 6, Ch 2, 2 Materials*.

2.1.6 Irrespective of the material used, the strength and supporting structure of all tunnels are to be examined by direct calculation procedures which are to be submitted. In no case are the scantlings to be taken as less than the Rule requirements for the surrounding structure. The strength of the hull structure in way of tunnels is to be maintained. The structure is to be adequately reinforced and compensated as necessary. All openings are to be suitably reinforced and have radiused corners.

2.1.7 Consideration is to be given to providing the inlet to the tunnel with a suitable guard to prevent the ingress of large objects into the rotodynamic machinery. The dimensions of the guard are to strike a balance between undue efficiency loss due to flow restriction and viscous losses, the size of object allowed to pass and susceptibility to clog with weed and other flow restricting matter.

2.1.8 The inlet profile of the tunnel is to be so designed as to provide a smooth uptake of water over the range of craft operating trims and avoid significant separation of the flow into the rotating machinery.

2.1.9 Single or multiple water jet unit installations having a total rated power in excess of 500kW are to be contained within their own watertight compartment. Other arrangements for maintaining watertight integrity may be specially considered depending on the size and installation layout.

2.1.10 For details of machinery requirements, *see Pt 12, Ch 2 Water Jet Systems*.

2.2 Water jet propulsion systems - Installation

2.2.1 Standard units built for `off the shelf' supply and which include the duct are to be installed strictly in accordance with the manufacturer's instructions, *see also Pt 6, Ch 5, 2.1 Water jet propulsion systems - Construction 2.1.4*.

2.2.2 Integral water jet ducts are to be constructed in accordance with the manufacturer's requirements and the relevant plans submitted as required by *Pt 6, Ch 5, 2.1 Water jet propulsion systems - Construction*.

2.2.3 Where load is transmitted into the transom and/or bottom shell, the thickness of the plating adjacent to the jet unit is to be increased. The increase in thickness is to be not less than 50 per cent of the calculated transom and bottom plating thicknesses respectively or 8 mm, whichever is the greater. Such reinforcement is to extend beyond the surrounding stiffening structure.

2.2.4 For `bolted in' units, hull receiving rings are to be of a material compatible with the hull. Scantlings of the receiving rings are to be as required by the jet unit manufacturer and suitably edge prepared prior to welding in place. The receiving ring is to be installed using an approved welding procedure. Where a manufacturer's specification is not provided, full details are to be submitted.

2.2.5 Bolt sizes and spacings are to be specified by the manufacturer, and are to be of suitable marine grade, insulated as appropriate and locked by suitable means.

2.2.6 Where studs are proposed for the receiving ring(s), the remaining thickness below the depth of blind tap is to be not less than the bottom shell plating thickness plus 2 mm. Bottoms of all blind taps are to be free of sharp corners.

2.2.7 The use of approved alignment resins may be considered where accurate seating and faying surfaces are required. Details are to be submitted for consideration and approval.

2.2.8 Where a water jet unit forms an integral part of the hull structure, such units are to be installed using an approved weld procedure and in accordance with the manufacturer's instructions. Materials to be welded are to be of compatible specifications.

2.2.9 Water jet units transmitting thrust into the transom structure are to be supported by a system of radial, athwartship and vertical stiffening. Drawings are to be accompanied by a set of detailed structural calculations. Where complex installations are proposed, a finite element model may be submitted in lieu of direct calculations.

2.2.10 Water jet units transmitting thrust to a bottom shell connection or intermediate tunnel connection are to be supported by additional stiffening, the details of which are to be submitted.

2.3 Foil support arrangements

2.3.1 The materials and construction of the lifting surface will be considered on a case by case basis.

2.3.2 The design and performance of the lifting surface is outside the scope of classification. However, when submitting structural plans for the hull connection installation, the designer/Builder is to define:

(a) Operating mode, i.e. fully submerged or surface piercing.
(b) Maximum operational speed for which approval is sought.
(c) Maximum, direct, bending, shear and torque loads generated by the foil at the point of attachment(s).
(d) The type of profile or section used, e.g. N.A.C.A.
(e) Supply of lift/drag profile.
(f) If the foil is fixed, movable or retractable.
(g) If the foil is fitted with control surfaces.
(h) If the vertical leg(s) act as a rudder(s).
(i) If shaft liners are carried to the foils at which support arrangements are provided.
(j) If water intakes/scoops are fitted.
(k) If propulsion units are fitted.

2.3.3 The scantlings and arrangements of foils and their supporting structure will require to be specially considered in the following cases where:

(a) Propulsion units are incorporated within the foil.
(b) Foils carry shaft support arrangements.
(c) The foils are of novel design.

2.3.4 Where fully submerged foils are `built-in' to the hull, the attachment area is to be contained within a watertight compartment. The structural arrangements of *Pt 6, Ch 5, 2.4 Surface drive mountings* are to be complied with as appropriate.

2.3.5 Where foils are to be bolted to the structural foundation, calculations are to be submitted to demonstrate that the effect of loading arising from high speed impact, grounding, fouling, etc. is limited to failure of the bolted connection. In all cases the structural and watertight integrity of the craft is to be maintained.

2.3.6 Attachment points of foils are in all cases to be contained within a watertight compartment.

2.3.7 Foils attached by riveted means are in addition to comply with *Pt 6, Ch 2, 4.20 Construction tolerances*.

2.3.8 Bow fairing doors fitted on forward retracting bow foils are to be weathertight and comply with *Pt 3, Ch 4 Closing Arrangements and Outfit*.

2.3.9 Aft bulkheads of bow foil compartments are to comply with the requirements for collision bulkheads as detailed in *Pt 6, Ch 3, 7.7 Collision bulkheads*.

2.3.10 Hydraulically operated retracting systems are to be equipped with low pressure and are to include a manual system of operation in the event of system failure.

2.3.11 A mechanical locking system is to be provided on retracting systems when the system is in both the operational and `stowed' conditions.

2.4 Surface drive mountings

2.4.1 Transoms through which surface drive systems pass and which are required to carry thrust, significant weight, torque, moment, etc. are to be adequately reinforced.

2.4.2 The thickness of transom plating in way is to be not less than 1,5 times the thickness of the adjacent plating or as advised by the drive manufacturer, whichever is the greater.

2.4.3 Steering rams are to be mounted on suitably reinforced areas of plating supported by additional internal stiffening, details of which are to be submitted for consideration.

2.5 Sea inlet scoops

2.5.1 Sea inlet scoops may be integral with or an appendage to the hull.

2.5.2 Scoops are to be suitably positioned to minimise ventilation.

2.5.3 Suitable protective arrangements are to be provided to minimise the ingress of debris. The net area through the proposed arrangement is to be not less than twice that of the valves connected to the scoop. Provision is to be made for clearing the scoops by the use of suitable means and proposals are to be submitted.

2.5.4 Scoops are to be contained within a watertight compartment.

2.5.5 The plating thickness in way of integral scoops is to be not less than 1,5 times the thickness of the adjacent shell plating, with additional reinforcement at the leading edge.

2.5.6 For craft navigating in ice, the arrangements will be specially considered on an individual basis.

2.6 Lifting appliance support arrangements

2.6.1 Crane pedestals are to be efficiently supported and in general, are to be carried through the deck and satisfactorily scarfed into the surrounding structure. Alternatively, crane pedestals may comprise a foundation, in which case the foundation and its supporting structure are to be of substantial construction. Proposals for other support arrangements will be specially considered.

2.6.2 The pedestal or proposed arrangement is to be designed with respect to the worst possible combinations of loads resulting from the crane self weight, live load, wind and crane accelerations together with those resulting from the craft's heel and trim.

2.6.3 Stowage arrangements are to be taken into account when calculating the loads applied to the pedestal.

2.6.4 The limiting stress coefficients for lifting appliance pedestals and foundation structural elements are given in *Table 7.3.1 Limiting stress coefficient for local loading*

2.6.5 The deck plating and underdeck stiffening in way of a lifting appliance pedestal are to be assessed using the same criteria used to assess the lifting appliance pedestal.

2.6.6 When submitting plans for the proposed foundation, the designer is to include design calculations covering the parameters indicated in *Pt 6, Ch 5, 2.6 Lifting appliance support arrangements 2.6.2* and *Pt 6, Ch 5, 2.6 Lifting appliance support arrangements 2.6.4*.

2.6.7 Insert plates are to be incorporated in the deck plating in way of crane foundations. The thickness of the insert plates is to be as required by the designer's calculations but in no case is to be taken as less than 1,5 times the thickness of the adjacent attached plating.

2.6.8 All inserts are to have well radiused corners and be suitably edge prepared prior to welding. All welding in way is to be double continuous and full penetration where necessary. Tapers are to be not less than three to one.

2.6.9 The support arrangements for life-saving appliance davits and cranes are, in general, to be in accordance with *Pt 3, Ch 9, 6.5 Support structure for life-saving appliances* of the *Rules and Regulations for the Classification of Ships, July 2021*.

2.7 Skirt attachment

2.7.1 The design and scantlings of the skirt are outside the scope of classification, however the designer/builder is to submit their proposals in respect of the attachment detail. The following supporting information is to be submitted:

(a) cushion pressure,
(b) calculations demonstrating that the effect of damage to the flexible membrane and/or the retaining section arising from high speed impact, grounding, fouling, etc. will not compromise the structural and watertight integrity of the craft.

2.7.2 The skirt is to be securely attached around its periphery and is to be suitably reinforced by the use of backing plates.

2.7.3 Where the skirt is retained by bolting, the retaining bars are to be as long as practicable with a fastener spacing of not more than 50 mm.

2.7.4 Where the design of the skirt is such that the flexible edge is retained by the use of a pre-formed channel, only the bolted hull connection of the preform to the hull structure is considered.

2.8 Trim tab arrangements

2.8.1 The shape, design and scantlings of the trim tabs are outside the scope of classification, however Lloyd's Register (hereinafter referred to as 'LR') is concerned with their attachment to the hull structure.

2.8.2 The designer/Builder is to submit the following:

(a) Detailed calculations indicating the maximum lift force generated by the tab for which acceptance is sought together with the corresponding speed and displacement.
(b) Details and calculations of the hull attachment.
(c) Details and calculations of the local internal reinforcement in way of the attachment.

2.8.3 Bearing materials used are to be of an approved type.

2.8.4 Fully submerged retractable trim tabs will be specially considered on a case by case basis.

2.9 Spray rails

2.9.1 Spray rails may be integrated into the hull structure or added in the form of an appendage on completion of the hull shell.

2.9.2 Where spray rails are integrated, they are to have a plating thickness not less than the adjacent bottom shell and additionally have a section modulus and inertia equivalent to that required for a longitudinal stiffener in the same position.

2.9.3 Where spray rails are added as an appendage, they are to be attached by double continuous welding and are additionally to comply with the strength requirements of *Pt 6, Ch 5, 2.9 Spray rails 2.9.2*.

2.9.4 Spray rails are to be supported by the internal stiffening arrangements and by additional local reinforcement as necessary.

2.9.5 In no case are the toes of spray rails to terminate on unsupported plating.

2.10 Other lifting surfaces

2.10.1 Other lifting surfaces not specifically covered by the Rules will be individually considered on the basis of submitted direct calculations.

2.10.2 Structure or hull shapes above the running waterline designed to generate aerodynamic lift may be individually considered on a case by case basis.

2.10.3 Aerodynamic, hydrodynamic and aero-hydrodynamic stability are outside the scope of classification and are subject to the approval of the National Administration concerned.

2.11 Propeller ducting

2.11.1 Where propellers are fitted within ducts/tunnels the plating thickness in way of the blades is to be increased by 50 per cent.

2.11.2 The tunnel wall in way of the propeller blades is to be additionally stiffened.

2.12 Ride control ducting and installation for Surface Effect Ships (SES)

2.12.1 Ducts penetrating the side inboard shell plating are to comply with the scantling requirements for side inboard structures, over their entire length in the appropriate material.

2.12.2 Ducts penetrating the wet-deck are to comply with the scantling requirements for wet-deck structures over their entire length in the appropriate material.

2.12.3 Open ends of ducts are to be fitted with a suitable protective grille.

2.12.4 The vent valve assembly, its design, construction and operation is outside the scope of classification and is the responsibility of the ride control system designer.

2.12.5 Details of the installation and securing arrangements of the vent valve assembly into the duct are to be submitted for approval.

2.13 Ramp supporting structure

2.13.1 The support structure (including hinges) in way of the interface between a ramp and the craft is to be assessed in accordance with the appropriate criteria given in *Ch 6, 2 Loading and design criteria* of the *Code for Lifting Appliances in a Marine Environment, July 2021*.

2.13.2 The loads that the ramp supporting structure will be subjected to are to be submitted by the designer or Shipbuilder. These loads are to be calculated in accordance with *Ch 6, 2 Loading and design criteria* of the *Code for Lifting Appliances in a Marine Environment, July 2021*. Load cases calculated in accordance with alternative standards can be accepted subject to agreement with Lloyd's Register (hereinafter referred to as LR).

2.13.3 Loads already existing in the supporting structure (other than those from the ramp) are to be superimposed if applicable.

2.13.4 Ramps forming part of the watertight integrity of the hull are also to be assessed in accordance with the applicable scantling requirements.

■ *Section 3* Vehicle decks

3.1 General

3.1.1 These requirements are applicable to longitudinally or transversely framed craft intended for the carriage of wheeled vehicles, or where wheeled vehicles are to be used for cargo handling.

3.1.2 The deck and supporting structure are to be designed on the basis of the maximum loading to which they may be subjected in service. Where applicable, the hatch covers are to be similarly designed. In no case, however, are the scantlings to be less than would be required for a weather or cargo deck, or hatch cover, as applicable.

3.1.3 Details of the deck loading resulting from the proposed stowage or operation of vehicles are to be supplied by the Builder. These details are to include axle and wheel spacing, the wheel load, type of tyre and tyre print dimensions for the vehicles. The vehicle types and wheel loads for which the vehicle decks, including hatch covers where applicable, have been approved are to be included in the craft's documentation and contained in a notice displayed on each deck. For design purpose, the wheel loading is to be taken as not less than 3,0 kN.

3.1.4 The scantling requirements are based on structural strength and limitations on stress and deflection, with no allowance made for wear and tear. Local reinforcement is to be fitted as necessary, particularly in way of vehicle lanes and passenger routes.

3.1.5 The webs of vehicle deck stiffening members are in no cases to be scalloped.

3.2 Definitions

3.2.1 **Load Area.** The load area is defined as the footprint area of an individual wheel or the area enclosing a group of wheels when the distance between footprints is less than the smaller dimension of the individual prints.

3.3 Deck plating

3.3.1 The thickness, t_p, of vehicle deck plating is to be taken as not less than:

$$t_p = \frac{\alpha s}{1000\sqrt{k_s}} \text{ mm}$$

where

P_1 = corrected patch load, in tonnes, obtained from *Table 5.3.1 Deck plate thickness calculation*

α = thickness coefficient obtained from *Figure 5.3.1 Tyre print chart*

β_p = tyre print coefficient used in *Figure 5.3.1 Tyre print chart*

= $\log_{10}\left(\frac{P_1 {k_s}^2}{s^2} \times 10^7\right)$

s and k_s are as defined in *Pt 6, Ch 5, 1.2 Symbols and definitions*.

Table 5.3.1 Deck plate thickness calculation

<table>
<tr><th>Symbols</th><th colspan="2">Expression</th></tr>
<tr><td rowspan="5">

a, s, u, and *v* as defined in *Figure 5.3.1 Tyre print chart*.

n = tyre correction factor as detailed in *Table 5.3.2 Tyre correction factor, n*

P_1 = corrected patch load, in tonnes

λ = dynamic magnification factor

P_w = load, in tonnes, on the tyre print. For closely spaced wheels the shaded area shown in *Figure 5.3.1 Tyre print chart* may be taken as the combined print

$f_1 \varphi_1$ = patch aspect ratio correction factor

$f_2 \varphi_1$ = panel aspect ratio correction factor

$f_3 \varphi_1$ = wide patch load factor

</td><td colspan="2">$P_1 = \varphi_1 \varphi_2 \varphi_3 \lambda P_w$</td></tr>
<tr><td>$\varphi_1 = \dfrac{2v_1 + 1,1s}{u_1 + 1,1s}$</td><td>$v_1 = v$, but $\leq s$
$u_1 = u$, but $\leq a$</td></tr>
<tr><td>$\varphi_2 = 1,0$
$= \dfrac{1}{1,3 - \dfrac{0,3}{s}(a-u)}$
$= 0,77\dfrac{a}{u}$</td><td>for $u \leq (a - s)$
for $a \geq u > (a - s)$
for $u > a$</td></tr>
<tr><td>$\varphi_3 = 1,0$
$= 0,6(s/v) + 0,4$
$= 1,2(s/v)$</td><td>for $v < s$
for $1,5 > (v/s) > 1,0$
for $(v/s) \geq 1,5$</td></tr>
<tr><td colspan="2">

λ = 1,25 for craft operating in G1
= $(1 + 0,35n)$ for craft operating in G2
= $(1 + 0,385n)$ for craft operating in G2A
= $(1 + 0,42n)$ for craft operating in G3
= $(1 + 0,49n)$ for craft operating in G4
= $(1 + 0,56n)$ for craft operating in G5
= $(1 + 0,70n)$ for craft operating in G6

G1, G2, G2A, G3, G4, G5 and G6 as defined in *Pt 1, Ch 2, 3.5 Service area restriction notations 3.5.5*.

</td></tr>
</table>

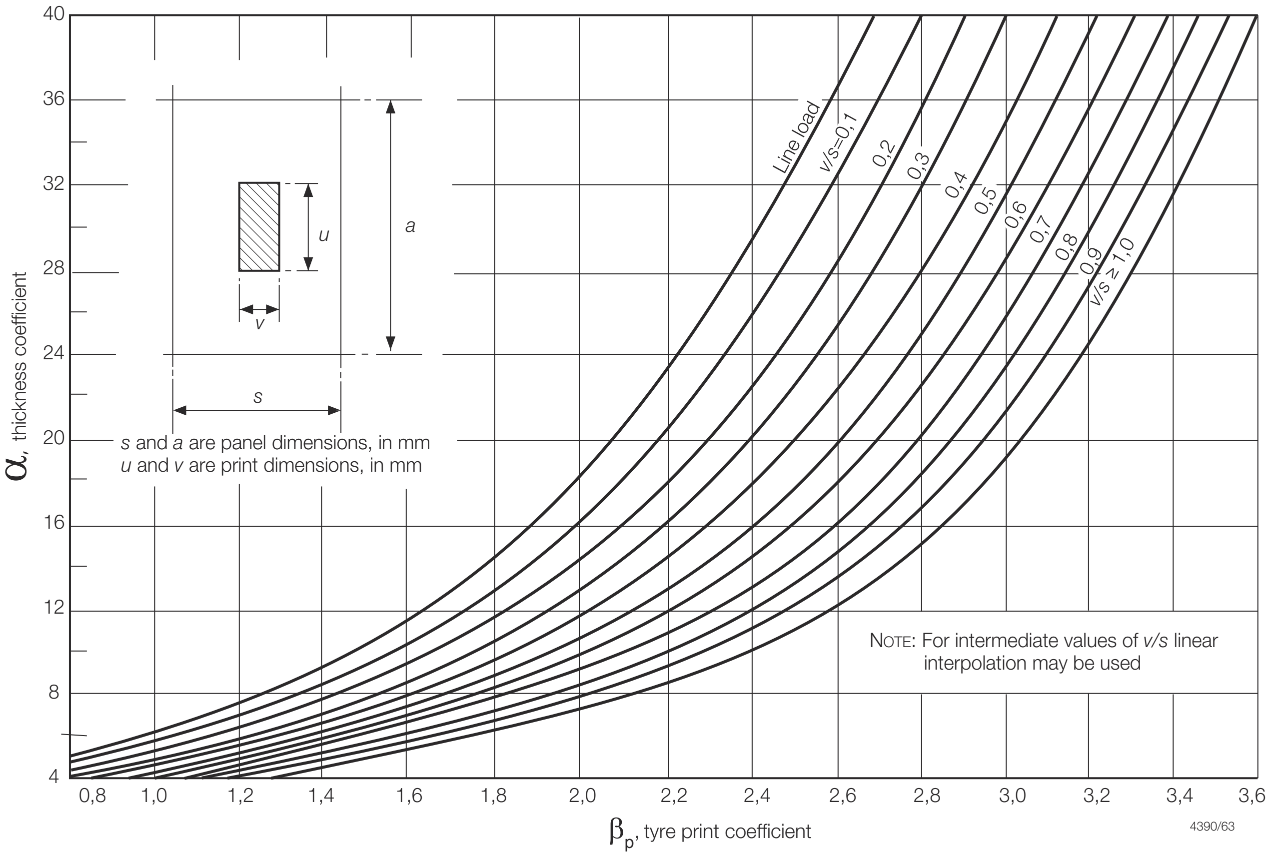


Figure 5.3.1 Tyre print chart

3.4 Secondary stiffening

3.4.1 The scantlings of vehicle deck stiffeners are to be as required to satisfy the most severe arrangement of print wheel loads in conjunction with the cargo/weather deck design head.

3.4.2 The minimum requirements for section modulus, inertia and web area of vehicle deck secondary stiffeners subject to wheel loading are to be calculated in accordance with *Table 5.3.3 Secondary stiffener requirements*, *see also Figure 5.3.1 Tyre print chart* and *Table 5.3.2 Tyre correction factor, n*.

Table 5.3.2 Tyre correction factor, *n*

Number of wheels in idealised patch	Pneumatic tyres correction factor, n	Solid rubber tyres correction factor, n
1	0,6	0,8
2 or more	0,75	0,9

Table 5.3.3 Secondary stiffener requirements

Scantling requirement	Load case	
	$d \leq l$	$d > l$
Section modulus (Z) (cm^3)	$Z = \left(\dfrac{P k_w \left(3l^2 - d^2\right) k_s}{24 l f_\sigma 235}\right) x10^3 + Z_{dk}$	$Z = \left(\dfrac{k_w P l^2 k_s}{10 d f_\sigma 235}\right) x10^3 + Z_{dk}$
Inertia (I) (cm^4)	$I = \left(\dfrac{f_\delta P k_w \left(2l^3 - 2d^2 l + d^3\right)}{384 E l}\right) \times 10^5 + I_{dk}$	$I = \left(\dfrac{f_\delta k_w P l^3}{384 E d}\right) \times 10^5 + I_{dk}$
Web area (A_w) (cm^2)	$A_w = \dfrac{10 P k_w \left(m^3 - 2m^2 + 2\right)}{2 f_\tau \tau_s} + A_{dk}$ where $m = d/l$	$A_w = \dfrac{k_w P l}{2 d f_\tau \tau_s} + A_{dk}$

Symbols

P = maximum effective load per wheel or group of wheels, in kN

l = overall secondary stiffener length, in metres

s = secondary stiffener spacing, in metres

k_s = higher tensile steel factor, as defined in *Pt 6, Ch 2, 2.4 Mechanical properties for design*

d = dimension of load area parallel to stiffener axis, in metres

E = Young's Modulus of elasticity of material, in N/mm^2

w = dimension of load area perpendicular to stiffener axis, in metres

k_w = lateral loading factor
= 1 for $w \leq s$
= s/w for $w > s$

f_σ = limiting bending stress coefficient taken from *Table 7.3.1 Limiting stress coefficient for local loading* in Chapter 7

f_τ = limiting shear stress coefficient taken from *Table 7.3.1 Limiting stress coefficient for local loading* in Chapter 7

f_δ = limiting deflection coefficient taken from *Table 7.2.1 Limiting deflection ratio* in Chapter 7

τ_s = shear stress of material, in N/mm^2 = $\dfrac{\sigma_s}{\sqrt{3}}$, where σ_s is as defined in *Pt 6, Ch 5, 1.2 Symbols and definitions*

Z_{dk}, I_{dk}, A_{dk} = For vehicle decks, stiffener requirements to be determined in accordance with *Pt 6, Ch 3, 8.7 Strength/Weather deck stiffening* and *Pt 6, Ch 3, 8.10 Cargo deck stiffening* using the appropriate design pressures, but not to be taken as less than 2kN/m^2.
= For helicopter decks, stiffener requirements to be determined in accordance with *Pt 6, Ch 3, 8.7 Strength/Weather deck stiffening* using the uniformly distributed loads given in *Table 5.6.2 Design load cases for deck stiffening and supporting structure*.

3.4.3 When two or more load areas are located simultaneously on the same stiffener span, the scantling requirements are to be specially considered on the basis of direct calculation.

3.4.4 Where continuous secondary stiffeners pass through the webs of primary members, they are to be fully collared or lugged in way. The shear stresses at the connections are to be in compliance with *Table 7.3.1 Limiting stress coefficient for local loading* in Chapter 7.

3.5 Primary stiffening

3.5.1 The scantlings of vehicle deck primary girders and transverse web frames are to be determined on the basis of direct calculation in association with the limiting permissible stress and deflection criteria contained in *Pt 6, Ch 7 Failure Modes Control*.

3.6 Securing arrangements

3.6.1 Details of the connections to the hull of vehicle securing arrangements are to be submitted for approval.

3.6.2 Deck fittings in way of vehicle lanes are to be recessed.

3.6.3 The vehicle deck structure is to be of adequate strength for the upward forces imposed at fixed securing points. Local reinforcement is to be fitted as necessary.

3.7 Access

3.7.1 Bow doors are to comply with the requirements of *Pt 6, Ch 5, 4 Bow doors*.

3.7.2 Where access to the vehicle deck is provided by side and stern doors, the doors are to have scantlings equivalent to the structure in which they are fitted, *see also Pt 3, Ch 4, 4 Side and stern doors and other shell openings*.

3.7.3 Doors providing pedestrian access between vehicle decks and accommodation spaces are to be gastight, have scantlings equivalent to the surrounding structure and where applicable are to comply with the requirements of *Pt 17 Fire Protection, Detection and Extinction*.

3.8 Hatch covers

3.8.1 The scantlings and arrangements of hatches and hatch covers located within vehicle decks are to be not less than that required by the Rules for the supporting structure in which such hatches are fitted. In general the end fixity of primary stiffening members is to be taken as simply supported. Local and secondary stiffening members may be either partially or fully fixed at their end connections dependent upon the proposed arrangement.

3.8.2 In no case, however, are the scantlings of plating and stiffeners to be less than would be required for a weather or cargo deck, or hatch cover, as applicable.

3.8.3 Where unusual arrangements of hatch cover stiffening are proposed, the scantlings of plating and stiffeners may be determined by direct calculations using a two-dimensional grillage model. Copies of calculations are to be submitted.

3.9 Heavy and special loads

3.9.1 Where heavy or special loads are proposed to be carried, the scantlings and arrangements of the deck structure will be individually considered on the basis of submitted calculations.

3.9.2 Due account is to be taken of the acceleration levels due to craft motion as applicable to particular items of heavy mass such as vehicles, containers, pallets, etc.

3.10 Direct calculations

3.10.1 LR will consider direct calculations for the derivation of scantlings as an alternative to and equivalent to those derived by Rule requirements. The assumptions made and the calculation procedures used are to be submitted for appraisal in accordance with *Pt 3, Ch 1, 2 Direct calculations*.

Section 4
Bow doors

4.1 Application

4.1.1 The requirements of this Section are applicable to the arrangement, strength and securing of bow doors, both the visor and the side opening type doors, and inner doors leading to a complete or long forward enclosed superstructure.

4.1.2 Other types of bow door will be specially considered.

4.2 General

4.2.1 The attention of Owners and Builders is drawn to the additional statutory regulations for bow doors that may be imposed by the National Authority.

4.2.2 Bow doors are to be situated above the freeboard deck. A watertight recess in the freeboard deck located forward of the collision bulkhead and above the deepest waterline fitted for arrangement of ramps or other related mechanical devices may be regarded as a part of the freeboard deck.

4.2.3 An inner door is to be fitted. The inner door is to be part of the collision bulkhead. The inner door need not be fitted directly above the bulkhead below, provided it is located within the limits specified for the position of the collision bulkhead, *see Pt 3, Ch 2, 4 Bulkhead arrangements*. A vehicle ramp may be arranged for this purpose, provided its position complies with *Pt 3, Ch 2, 4 Bulkhead arrangements* and the ramp is weathertight over its complete length. In this case the upper part of the ramp higher than 2,3 m above the freeboard deck may extend forward of the limit specified in *Pt 3, Ch 2, 4 Bulkhead arrangements*. If this is not possible a separate inner weathertight door is to be installed, as far as practicable within the limits specified for the position of the collision bulkhead.

4.2.4 Bow doors are to be fitted as to ensure tightness consistent with operational conditions and to give effective protection to inner doors. Inner doors forming part of the collision bulkhead are to be weathertight over the full height of the cargo space and arranged with fixed sealing supports on the aft side of the doors.

4.2.5 Bow doors and inner doors are to be arranged so as to preclude the possibility of the bow door causing structural damage to the inner door or to the collision bulkhead in the case of damage to or detachment of the bow door. If this is not possible, a separate inner weathertight door is to be installed, as indicated in *Pt 6, Ch 5, 4.2 General 4.2.3*.

4.2.6 The requirements for inner doors are based on the assumption that vehicles are effectively lashed and secured against movement in the stowed position.

4.3 Symbols and definitions

4.3.1 The symbols used in this Section are defined as follows:

A_s = area stiffener web, in cm^2

A_x = area, in m^2, of the transverse vertical projection of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, whichever is the lesser, as shown in *Figure 5.4.2 Bow visor (upward hinging)*

A_y = area, in m^2, of the longitudinal vertical projection of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, whichever is the lesser

A_z = area of the horizontal projection of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, in m^2, whichever is the lesser, as shown in *Figure 5.4.2 Bow visor (upward hinging)*

a_{bv} = vertical distance, in metres, from visor pivot to the centroid of the transverse vertical projected area of the visor door, as shown in *Figure 5.4.2 Bow visor (upward hinging)*

b_{bv} = horizontal distance, in metres, from visor pivot to the centroid of the horizontal projected area of the visor door, as shown in *Figure 5.4.2 Bow visor (upward hinging)*

c_{bv} = horizontal distance, in metres, from visor pivot to the centre of gravity of visor mass, as shown in *Figure 5.4.2 Bow visor (upward hinging)*

d_{bv} = Vertical distance, in metres, from bow door pivot to the centre of gravity of the bow door, as shown in *Figure 5.4.2 Bow visor (upward hinging)*

h = height of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, in metres, whichever is the lesser, as shown in *Figure 5.4.1 Measurement of α_f and β_e*

l_d = length of the door at a height h/2 above the bottom of the door, in m, as shown in *Figure 5.4.2 Bow visor (upward hinging)*

Q_{bd} = shear force, in kN, in the stiffener calculated by using uniformly distributed external pressure P_e as given in *Pt 6, Ch 5, 4.5 Design loads 4.5.1*

W_{bv} = mass of the visor door, in tonnes

W = breadth of the door at a height h/2 above the bottom of the door, in metres, as shown in *Figure 5.4.2 Bow visor (upward hinging)*

σ = bending stress, in N/mm^2

σ_{eq} = equivalent stress, in N/mm^2

= $\sqrt{\sigma^2 + 3\tau^2}$

σ_s = specified minimum yield strength of the material, in N/mm^2

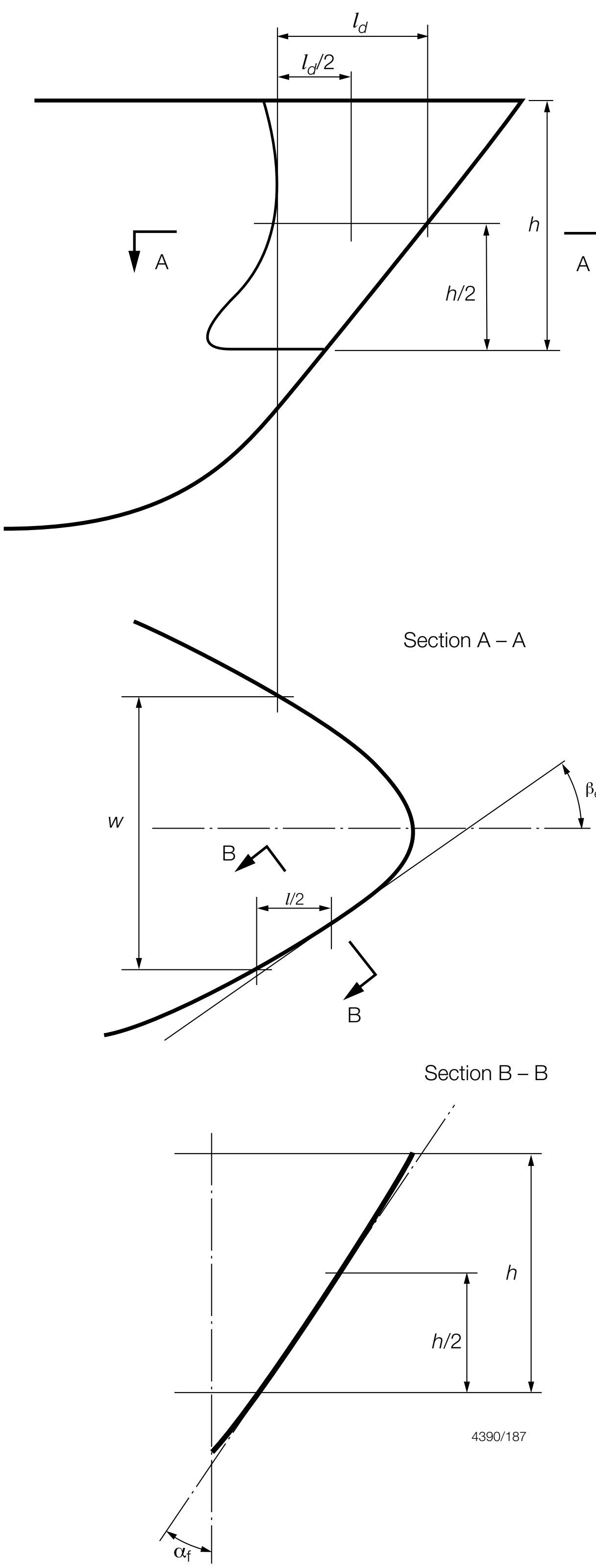


Figure 5.4.1 Measurement of α_f and β_e

4.3.2 **Locking device.** A device that locks a securing device in the closed position.

4.3.3 **Securing device.** A device used to keep the door closed by preventing it from rotating about its hinges.

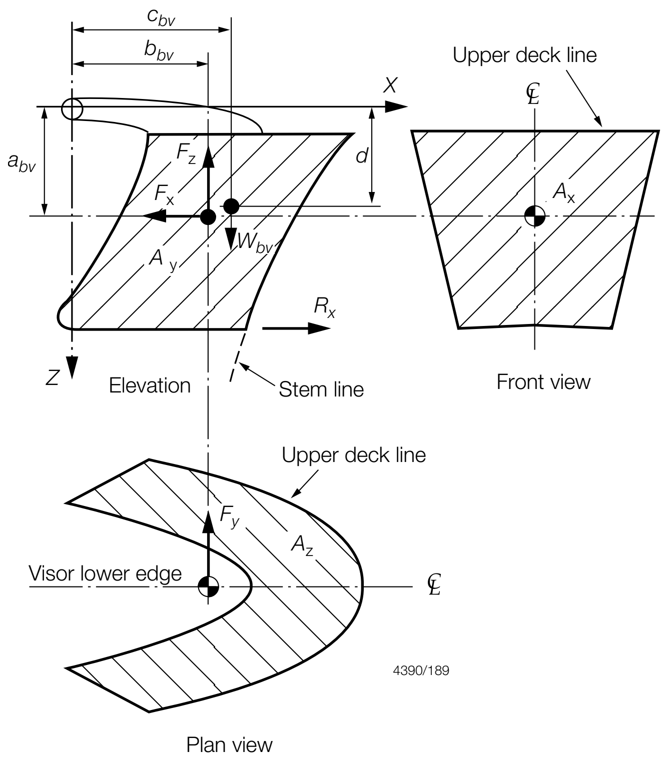


Figure 5.4.2 Bow visor (upward hinging)

4.3.4 **Side-opening doors.** Side-opening doors are opened either by rotating outwards about a vertical axis through two or more hinges located near the outboard edges or by horizontal translation by means of linking arms arranged with pivoted attachments to the door and the craft. It is anticipated that side-opening doors are arranged in pairs.

4.3.5 **Supporting device.** A device used to transmit external or internal loads from the door to a securing device and from the securing device to the craft's structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, that transmits loads from the door to the craft's structure.

4.3.6 **Visor doors.** Visor doors are opened by rotating upwards and outwards about a horizontal axis through two or more hinges located near the top of the door and connected to the primary structure of the door by longitudinally arranged lifting arms.

4.4 Strength criteria

4.4.1 Scantlings of the primary members, securing and supporting devices of bow doors and inner doors are to be able to withstand the design loads defined in *Pt 6, Ch 5, 4.5 Design loads*. The shear, bending and equivalent stresses are not to exceed $80/k_s$ N/mm^2, $120/k_s$ N/mm^2 and $150/k_s$ N/mm^2 respectively where k_s is as defined in *Pt 6, Ch 5, 1.2 Symbols and definitions*

4.4.2 The buckling strength of primary members is to be verified as being adequate, *see Pt 6, Ch 7, 4 Buckling control*.

4.4.3 For steel to steel bearings in securing and supporting devices, the nominal bearing pressure calculated by dividing the design force by the projected bearing area is not to exceed 80 per cent of the yield stress of the bearing material. For other bearing materials, the permissible bearing pressure is to be determined according to the manufacturer's specification.

4.4.4 The arrangement of securing and supporting devices is to be such that threaded bolts do not carry support forces. The maximum tension in way of threads of steel bolts not carrying support forces is not to exceed $125/k_s$ N/mm^2 where k_s is as defined in *Pt 6, Ch 5, 1.2 Symbols and definitions*.

4.5 Design loads

4.5.1 The design external pressure, P_e, for the determination of scantlings for primary members, securing and supporting devices of bow doors is to be taken not less than the following:

$$P_e = 2,75\,\lambda_G C_H \left(0,22 + 0,15 \tan \alpha_f\right) \left(0,4 V_{max} \sin \beta_e + 0,6 L_R^{0.5}\right)^2 \text{ kN/m}^2$$

where

V_{max} = maximum speed, in knots, as defined in *Pt 1, Ch 2, 2.2 Definitions 2.2.11*

L_R = Rule length of craft, in metres, as defined in *Pt 3, Ch 1, 6 Definitions*

λ_G = Service group factor for mono-hull craft, *see Pt 1, Ch 2 Classification Regulations*

= 0,5 for Groups 1 and 2

= 0,6 for Group 3

= 0,8 for Group 4

= 1,0 for Groups 5 and 6

= For multi-hull craft, λ_G will be specially considered and may be reduced where the freeboard is significant

C_H = $0,0125 L_R$ for $L_R < 80$ m

= 1,0 for $L_R \geq 80$ m

α_f = flare angle, in degrees, at the point to be considered, defined as the angle between a vertical line and the tangent to the side shell plating, measured in a vertical plane normal to the horizontal tangent to the shell plating, *see Figure 5.4.1 Measurement of α_f and β_e*

β_e = entry angle, in degrees, at the point to be considered, defined as the angle between a longitudinal line parallel to the centreline and the tangent to the shell plating in a horizontal plane, *see Figure 5.4.1 Measurement of α_f and β_e* .

4.5.2 The design external forces, F_x, F_y and F_z, in kN, for the determination of scantlings of securing and supporting devices of bow doors are taken to be not less than $P_e A_x$, $P_e A_y$ and $P_e A_z$ respectively.

Where

P_e = is the external pressure, defined in *Pt 6, Ch 5, 4.5 Design loads 4.5.1*, with the flare angle, α_f, and the entry angle, β_e, measured at the point on the bow door

$l_d/2$ = aft of the stem line on the plane, and

$h/2$ = above the bottom of the door, as shown in *Figure 5.4.1 Measurement of α_f and β_e*

A_x, A_y, A_z and h as defined in *Pt 6, Ch 5, 4.3 Symbols and definitions 4.3.1*.

4.5.3 For bow doors, including bulwark, of unusual form or proportions, the areas used for the determination of the design values of external forces will be specially considered.

4.5.4 For visor doors the closing moment, M_y, under external loads, is to be taken as:

$$M_y = F_x a_{bv} + 10 W_{bv} c_{bv} - F_z b_{bv} \text{ kNm}$$

where W_{bv}, a_{bv}, b_{bv} and c_{bv} are as defined in *Pt 6, Ch 5, 4.3 Symbols and definitions 4.3.1*, F_x and F_z as defined in *Pt 6, Ch 5, 4.5 Design loads 4.5.2*.

4.5.5 The lifting arms of a visor and its supports are to be dimensioned for the static and dynamic forces applied during the lifting and lowering operations, and a minimum wind pressure of 1,5kN/m^2 is to be taken.

4.5.6 The design external pressure, in kN/m^2, for the determination of scantlings for primary members, securing and supporting devices and surrounding structure of inner doors is to be taken as the greater of $0,45 L_R$ and $10 h_2$. where h_2 is the distance, in m, from the load point to the top of the cargo space and L_R as defined in *Pt 3, Ch 1, 6.2 Principal particulars 6.2.1*.

4.5.7 The design internal pressure for the determination of scantlings for securing devices of inner doors is not to be taken less than 25 kN/m^2.

4.6 Scantlings of bow doors

4.6.1 The strength of bow doors is to be commensurate with that of the surrounding structure.

4.6.2 Bow doors are to be adequately stiffened and means are to be provided to prevent lateral or vertical movement of the doors when closed. For visor doors adequate strength for the opening and closing operations is to be provided in the connections of the lifting arms to the door structure and to the craft structure.

4.6.3 The thickness of the bow plating is not to be less than that required for the side shell plating, using bow door stiffener spacing, but in no case less than the minimum required thickness of fore end shell plating.

4.6.4 The section modulus of horizontal or vertical stiffeners is not to be less than that required for end framing. Consideration is to be given, where necessary, to differences in fixity between craft's frames and bow doors stiffeners.

4.6.5 The stiffener webs are to have a net sectional area A_s, not less than:

$$A_s = \frac{23,5 Q_{bd}}{\sigma_s} \text{ cm}^2$$

where A_s, Q_{bd} and σ_s are as defined in *Pt 6, Ch 5, 4.3 Symbols and definitions 4.3.1*.

4.6.6 The bow door secondary stiffeners are to be supported by primary members constituting the main stiffening of the door.

4.6.7 The primary members of the bow door and the hull structure in way are to have sufficient stiffness to ensure integrity of the boundary support of the door.

4.6.8 Scantlings of the primary members are generally to be supported by direct calculations in association with the external pressure given in *Pt 6, Ch 5, 4.5 Design loads 4.5.1* and permissible stresses given in *Pt 6, Ch 5, 4.4 Strength criteria 4.4.2*.

4.7 Scantlings of inner doors

4.7.1 Scantlings of the primary members are generally to be supported by direct calculations in association with the external pressure and permissible stresses given in *Pt 6, Ch 5, 4.4 Strength criteria 4.4.1*. In general, formulae for simple beam theory may be applied.

4.7.2 Where inner doors also serve as a vehicle ramps, the scantlings are not to be less than those required for vehicle decks.

4.7.3 The distribution of forces acting on the securing and supporting devices is, in general, to be supported by direct calculations taking into account the flexibility of the structure and actual position and stiffness of the supports.

4.8 Securing and supporting of bow doors

4.8.1 Bow doors are to be fitted with adequate means of securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure. The hull supporting structure in way of the bow doors is to be suitable for the same design loads and design stresses as the securing and supporting devices. Where packing is required, the packing material is to be of a comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered. Maximum design clearance between securing and supporting devices is, in general, not to exceed 3 mm. A means is to be provided for mechanically fixing the door in the open position.

4.8.2 Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be included and considered to calculate the reaction forces acting on the devices. Small and/or flexible devices such as cleats intended to provide load compression of the packing material are, in general, not to be included in the calculations called for in *Pt 6, Ch 5, 4.8 Securing and supporting of bow doors 4.8.8*. The number of securing and supporting devices are, in general, to be the minimum practical whilst taking into account the requirements for redundant provision given in *Pt 6, Ch 5, 4.8 Securing and supporting of bow doors 4.8.9* and *Pt 6, Ch 5, 4.8 Securing and supporting of bow doors 4.8.10* and the available space for adequate support in the hull structure.

4.8.3 For opening outwards visor doors, the pivot arrangement is generally to be such that the visor is self closing under external loads, that is $M_y > 0$. Moreover, the closing moment, M_y, as given in *Pt 6, Ch 5, 4.5 Design loads 4.5.4* is to be not less than:

$$M_y = 10 W_{bv} c_{bv} + 0,1 \left(a_{bv}^2 + b_{bv}^2\right)^{0,5} \left(F_x^2 + F_z^2\right)^{0,5}$$

where W_{bv}, a_{bv}, b_{bv} and c_{bv} are as defined in *Pt 6, Ch 5, 4.3 Symbols and definitions 4.3.1*, F_x and F_z are as defined in *Pt 6, Ch 5, 4.5 Design loads 4.5.2*.

4.8.4 Securing and supporting devices are to be adequately designed so that they can withstand the reaction forces within the permissible stresses given in *Pt 6, Ch 5, 4.4 Strength criteria 4.4.1*.

4.8.5 For **visor doors** the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self weight of the door.

Case 1	F_x and F_z.
Case 2	$0,7F_y$ acting on each side separately together with $0,7F_x$ and $0,7F_z$.

where F_x, F_y and F_z are to be determined as indicated in *Pt 6, Ch 5, 4.5 Design loads 4.5.2* and applied at the centroid of projected areas.

4.8.6 For **side-opening** doors the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self weight of the door:

Case 1	F_x , F_y and F_z acting on both doors.
Case 2	$0,7\,F_x$ and $0,7F_z$acting on both doors and $0,7F_y$ acting on each door separately.

where F_x, F_y and F_z are to be determined as indicated in *Pt 6, Ch 5, 4.5 Design loads 4.5.2* and applied at the centroid of projected areas.

4.8.7 The support forces as determined according to *Pt 6, Ch 5, 4.8 Securing and supporting of bow doors 4.8.5* and *Pt 6, Ch 5, 4.8 Securing and supporting of bow doors 4.8.6* are generally to give rise to a zero moment about the transverse axis through the centroid of the area A_x. For visor doors, longitudinal reaction forces of pin and/or wedge supports at the door base contributing to this moment are not to be of the forward direction.

4.8.8 The distribution of the reaction forces acting on the securing and supporting devices may require to be supported by direct calculations taking into account the flexibility of the hull structure and the actual position and stiffness of the supports.

4.8.9 The arrangement of securing and supporting devices in way of these securing devices is to be designed with redundancy so that in the event of failure of any single securing or supporting device the remaining devices are capable to withstand the reaction forces without exceeding by more than 20 per cent the permissible stresses as given in *Pt 6, Ch 5, 4.4 Strength criteria 4.4.1*.

4.8.10 For visor doors, two securing devices are to be provided at the lower part of the door, each capable of providing the full reaction force required to prevent opening of the door within the permissible stresses given in *Pt 6, Ch 5, 4.4 Strength criteria 4.4.1*. The opening moment, M_o, to be balanced by this reaction force, is not to be taken less than:

$$M_o = 10W_{bv}d_{bv} + 5A_x a_{bv} \text{ kNm}$$

where W_{bv}, A_x, d_{bv} and a_{bv} as defined in *Pt 6, Ch 5, 4.3 Symbols and definitions 4.3.1*.

4.8.11 For visor doors, the securing and supporting devices excluding the hinges should be capable of resisting the vertical design force (F_z - $10W_{bv}$), in kN, within the permissible stresses given in *Pt 6, Ch 5, 4.4 Strength criteria 4.4.1*.

4.8.12 All load transmitting elements in the design load path, from door through securing and supporting devices into the craft structure, including welded connections, are to be the same strength.

4.8.13 For side-opening doors, thrust bearing has to be provided in way of girder ends at the closing of the two leaves to prevent one leaf to shift towards the other one under effect of unsymmetrical pressure (*see Figure 5.4.3 Typical thrust bearing*). Each part of the thrust bearing has to be kept secured on the other part by means of securing devices. Any other arrangements serving the same purpose are to be submitted for appraisal.

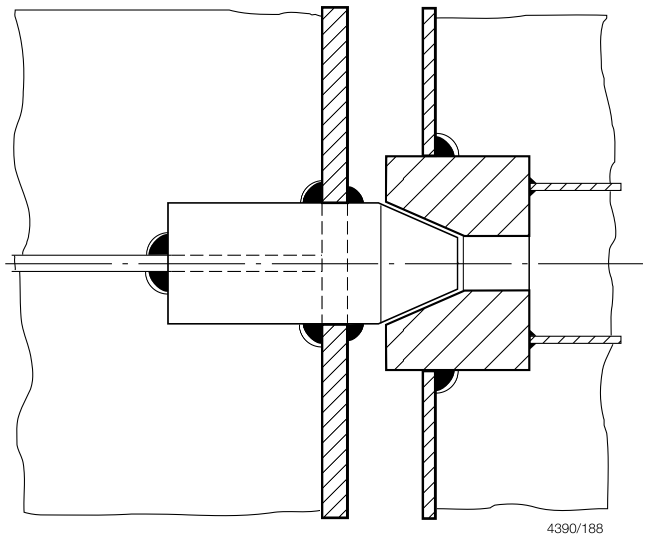


Figure 5.4.3 Typical thrust bearing

4.9 Securing and locking arrangement

4.9.1 Securing devices are to be simple to operate and easily accessible. Securing devices are to be equipped with mechanical locking arrangements (self locking or separate arrangement), or be of the gravity type. The opening and closing systems as well as securing and locking devices are to be interlocked in such a way that they can only operate in the proper sequence.

4.9.2 Bow doors and inner doors giving access to vehicle decks are to be provided with an arrangement for remote control, from a position above the freeboard deck, of:

(a) the closing and opening of the doors; and
(b) associated securing and locking devices for every door.

Indication of the open/closed position of every door and every securing and locking device is to be provided at the remote control stations. The operating panels for operation of doors are to be inaccessible to unauthorised persons. A notice plate, giving instructions to the effect that all securing devices are to be closed and locked before leaving harbour, is to be placed at each operating panel and is to be supplemented by warning indicator lights.

4.9.3 Where hydraulic securing devices are applied, the system is to be mechanically lockable in closed position so that in the event of loss of the hydraulic fluid, the securing devices remain locked. The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits when in closed position.

4.9.4 Separate indicator lights and audible alarms are to be provided on the navigation bridge and on the operating panel to show that the bow door and inner door are closed and that their securing and locking devices are properly positioned. The indication panel is to be provided with a lamp test function. The indicator lights are to be provided with a permanent power supply, and arrangements are to be such that it is not possible to turn off these lights in service.

4.9.5 The indicator system is to be designed on the fail-safe principle and is to show by visual alarms if the door is not fully closed and not fully locked and by audible alarms if securing devices become open or locking devices become unsecured. The power supply for the indicator system is to be independent of the power supply for operating and closing the doors. The sensors of the indicator system are to be protected from water, ice formation and mechanical damage.

4.9.6 The indication panel on the navigation bridge is to be equipped with a mode selection function `harbour/sea voyage', so arranged that audible alarm is given if the craft leaves harbour with the bow door or inner door not closed and with any of the securing devices not in the correct position.

4.9.7 A water leakage detection system with audible alarm and television surveillance is to be arranged to provide an indication to the navigation bridge and to the engine control room of leakage through the inner door.

4.9.8 Between the bow door and the inner door a television surveillance system is to be fitted with a monitor on the navigation bridge and in the engine control room. The system is to be able to monitor the position of doors and a sufficient number of their securing devices. Special consideration is to be given for lighting and contrasting colour of objects under surveillance.

4.9.9 A drainage system is to be arranged in the area between bow door and ramp, as well as in the area between the ramp and inner door where fitted. The system is to be equipped with an audible alarm function to the navigation bridge for water level in these areas exceeding 0,5 m above the car deck level.

4.10 Operating and Maintenance Manual

4.10.1 An Operating and Maintenance Manual for the bow door and inner door is to be provided on board and contain necessary information on:

(a) main particulars and design drawings;
(b) service conditions, e.g. service area restrictions and acceptable clearances for supports;
(c) maintenance and function testing;
(d) register of inspections and repairs.

This manual is to be submitted for approval.

4.10.2 Documented operating procedures for closing and securing the bow door and inner door are to be kept on board and posted at an appropriate place.

■ *Section 5* Movable decks

5.1 Classification

5.1.1 Movable decks other than those described in *Pt 6, Ch 5, 5.1 Classification 5.1.2* are not a classification item, although consideration must be given to associated supporting structure. Where movable decks are fitted, it is recommended that they be based on the requirements of this Section.

5.1.2 At the Owner's or Builder's request, however, movable decks will be included as a classification item, and the class notation **Movable decks** will be entered in the *Register Book*. In such cases, all movable decks on board the ship are to comply with the requirements of this Section.

5.2 Arrangements and designs

5.2.1 Movable decks are generally to be constructed as pontoons comprising a web structure with top decking. Other forms of construction will be individually considered.

5.2.2 Positive means of control are to be provided to secure decks in the lowered position.

5.2.3 The decks are to be efficiently supported, and hinges, pillars, chains or other means (or a combination of these) are to be designed on the basis of the imposed loads. Where supporting chains and fittings are required, they are to have a factor of safety of at least two on the proof load.

5.2.4 Plans showing the proposed scantlings and arrangements of the system are to be submitted.

5.2.5 Where it is proposed to stow the pontoons on deck, when not in use, details of the proposals for racks, fittings, etc. are to be submitted for consideration.

5.3 Loading

5.3.1 Details of the deck loading resulting from the proposed stowage arrangements of vehicles are to be supplied by the Shipbuilder. These details are to include the axle and wheel spacing, the wheel load, type of tyre and tyre print dimensions for the vehicles. For design purposes the wheel loading is to be taken as not less than 3,0 kN, *see Pt 6, Ch 5, 3 Vehicle decks*.

5.3.2 Where it is proposed also to use the decks for general cargo, the design loadings are to be submitted for consideration.

5.4 Scantling requirements

5.4.1 The scantlings and arrangements of removable decks are to be not less than those required by the Rules for the supporting structure in which the movable decks are fitted. In general the end fixity of primary stiffening members is to be taken as simply supported. Local and secondary stiffening members may be either partially or fully fixed at their end connections dependent upon the proposed arrangement.

5.5 Deflection

5.5.1 Where wheeled vehicles are to be used, the supporting arrangements are to be such that the movement at the edge of one pontoon relative to the next does not exceed 50 mm during loading or unloading operations.

■ *Section 6* Helicopter landing areas

6.1 General

6.1.1 The landing area may be located on an appropriate area of the weather deck or on a platform specifically designed for this purpose and permanently connected to the craft structure.

6.1.2 Attention is drawn to the requirements and guidance of National and other Authorities concerning the construction of helicopter landing platforms and the operation of helicopters as they affect the ship. These include SOLAS Reg.II-2/18 and Reg.III/28 as applicable as well as the *International Chamber of Shipping (ICS) Guide to Helicopter/Ship Operations and the International Aeronautical Search and Rescue Manual (IAMSAR) and CAP437 Standards for Offshore Helicopter Landing Areas*.

6.1.3 Attention is drawn to the requirements of National and other Authorities concerning the construction of helicopter landing platforms and the operation of helicopters as they affect the craft.

6.1.4 Plans are to be submitted showing the proposed scantlings and arrangements of the structure. The type, size and weight of helicopters to be used are also to be indicated. Details of the helicopter types to be used are to be included in the craft's documentation, and be contained in a notice displayed on the helicopter landing deck.

6.1.5 Where the landing area forms part of a weather or erection deck, the scantlings are to be not less than those required for decks in the same position.

6.1.6 The requirements for fire protection, detection and extinction are outside the scope of classification, and are therefore to comply with requirements of the National Authority.

6.2 Arrangements

6.2.1 The landing area is to be sufficiently large to allow for the landing and manoeuvring of the helicopter, and is to be approached by a clear landing and take-off sector complying in extent with the applicable regulations.

6.2.2 The landing area is to be free of any projections above the level of the deck. Projections in the zone surrounding the landing area are to be kept below the heights permitted by the regulations.

6.2.3 Suitable arrangements are to be made to minimise the risk of personnel or machinery sliding off the landing area. A non-slip surface and anchoring devices, and in the case of independent platforms, safety nets, are to be provided.

6.2.4 Arrangements are to be made for drainage of the platform, including drainage of spilt fuel.

6.2.5 Details of arrangements for securing the helicopter to the deck are to be submitted for approval.

6.3 Landing area plating

6.3.1 The deck plate thickness, t_{p}, within the landing area is to be not less than:

$$t_{\text{p}} = \frac{\alpha s}{1000\sqrt{k_{\text{s}}}}$$

α = thickness coefficient obtained from *Figure 5.3.1 Tyre print chart*

β_p = tyre print coefficient used in *Figure 5.3.1 Tyre print chart*

$$= \log_{10}\left(\frac{P_1 k_s^{\,2}}{s^2} \times 10^7\right)$$

where

s and k_s are defined in *Pt 6, Ch 5, 1.2 Symbols and definitions*.

The plating is to be designed for the emergency landing case taking

$$P_1 = 2,5\, \varphi_1 \varphi_2 \varphi_{3f}\, \gamma P_W \textit{ tonnes}$$

in which φ_1, φ_2, φ_3 are to be determined from *Table 5.3.1 Deck plate thickness calculation*

f = 1,15 for landing decks over manned spaces, e.g. deckhouses, bridges, control rooms, etc.

= 1,0 elsewhere

P_h = the maximum all up weight of the helicopter, in tonnes

P_w = landing load on the tyre print, in tonnes;

For helicopters with a single main rotor, P_w is to be taken as P_h divided equally between the two main undercarriage wheels.

For helicopters with tandem main rotors, P_w is to be taken as P_h distributed between all main undercarriage wheels in proportion to the static loads they carry.

For helicopters fitted with landing gear consisting of skids, P_w is to be taken as P_h distributed in accordance with the actual load distribution given by the airframe manufacturer. If this is unknown, P_w is to be taken as $1/6P_h$ for each of the two forward contact points and $1/3P_h$ for each of the two aft contact points. The load may be assumed to act as a 300 mm x 10 mm line load at each end of each skid when applying *Figure 5.3.1 Tyre print chart*.

γ = a location factor given in *Table 5.6.1 Location factor, γ*

For wheeled undercarriages, the tyre print dimensions specified by the manufacturer are to be used for the calculation. Where these are unknown it may be assumed that the print area is 300 mm x 300 mm and this assumption is to be indicated on the submitted plan.

For skids and tyres with an asymmetric print, the print is to be considered oriented both parallel and perpendicular to the longest edge of the plate panel and the greatest corresponding value of α taken from *Figure 5.3.1 Tyre print chart*.

Table 5.6.1 Location factor, γ

Location	γ	
On decks forming part of the hull girder:		
(a) within 0,4L_R amidships	0,71	Values for intermediate locations are to be determined by interpolation
(b) at the F.P. or A.P.	0,6	
Elsewhere	0,6	

6.4 Deck stiffening and supporting structure

6.4.1 The helicopter deck stiffening and the supporting structure are to be designed for the load cases given in *Table 5.6.2 Design load cases for deck stiffening and supporting structure*, with the helicopter being positioned so as to produce the most severe loading condition for each structural member under consideration.

Table 5.6.2 Design load cases for deck stiffening and supporting structure

Loadcase	Loads (tonnes)			
	Landing area		Supporting structure, *see* Note 1	
	UDL, in kN/m^2	Helicopter patch load *see* Note 2	Self weight	Horizontal load *see* Note 2
(1) Overall distributed loading	2	-	-	-
(2) Helicopter emergency landing	0,5	$2,5 P_w f$	W_h	$0,5 P_h$
(3) Normal Usage	0,5	$1,5 P_w$	W_h	$0,5 P_h + 0,5 W_h$
Symbols				
P_h, P_w and f are as defined in *Pt 6, Ch 5, 6.3 Landing area plating 6.3.1*. *UDL* = Uniformity distributed vertical load over entire landing area W_h = structural self-weight of helicopter platform, in tonnes				
Note 1. For the design of the supporting structure for helicopter platforms applicable self weight and horizontal loads are to be added to the landing area loads. Note 2. The helicopter is to be so positioned as to produce the most severe loading condition for each structural member under consideration.				

6.4.2 The minimum requirements for section modulus, inertia and web area of secondary stiffeners are to be in accordance with *Table 5.3.3 Secondary stiffener requirements*.

6.4.3 For primary stiffening, and where a grillage arrangement is adopted, it is recommended that direct calculation procedures be used to determine the scantling requirements, in association with the limiting permissible stress criteria given in *Pt 6, Ch 7 Failure Modes Control*. A copy of the calculations is to be submitted for consideration.

■ *Section 7*
Strengthening requirements for navigation in ice conditions

7.1 General

7.1.1 Where an ice class notation is to be included in the class of a craft, the scantlings will require special consideration, *see Pt 3, Ch 2, 9 Navigation in ice*.

7.2 Shell plating

7.2.1 Changes in plating thicknesses in the longitudinal direction are to take place gradually.

7.2.2 In general all welded seams and butts in way of the main ice belt are to be dressed smooth.

■ *Section 1* General

1.1 Application

1.1.1 The requirements for longitudinal and transverse global strength for mono-hull and multi-hull craft of steel construction, are contained within this Chapter. Due consideration is taken of the dynamic effects, where appropriate, in both the crest and trough wave landing conditions.

1.2 Symbols and definitions

1.2.1 The symbols and definitions applicable to this Chapter are defined below or in the appropriate sub-Section.

L_R = Rule length of the craft, in metres

B = moulded breadth of craft, *see Pt 3, Ch 1, 6.2 Principal particulars 6.2.1*, in metres (to be taken as the breadth of a single hull for multi-hull craft)

l = overall span length of stiffening member, in metres

l_e = effective span length of stiffening member, in metres

p = design pressure as appropriately given in *Pt 3 General Requirements and Constructional Arrangements*, in kN/m^2

s = spacing of stiffener, in mm

t_p = thickness of plating, in mm

σ_S = specified minimum yield strength of the material, in N/mm^2

β = panel aspect ratio correction, see *Pt 6, Ch 3, 1.15 Aspect ratio correction*

τ_S = shear stress of material, in N/mm^2

$$= \frac{\sigma_s}{\sqrt{3}}$$

1.2.2 The strength deck is to be taken as follows:

(a) Where there is a complete upper deck the strength deck is the upper deck.
(b) Where the upper deck is stepped, as in the case of raised quarterdeck craft, the strength deck is stepped as shown in *Figure 6.1.1 Strength deck*.

1.3 General

1.3.1 The additional pressures arising from the influence of the global loading are considered in the determination of the longitudinal strength requirements for local and secondary stiffening and bottom shell plating.

1.3.2 In general, the effective sectional area of continuous longitudinal strength members, after deduction of openings, is to be used for the calculation of midship section modulus.

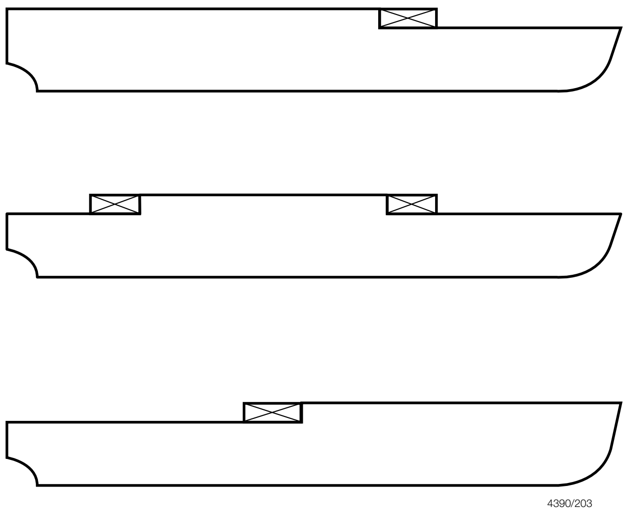


Figure 6.1.1 Strength deck

1.3.3 Structural members which contribute to the overall hull girder strength are to be carefully aligned so as to avoid discontinuities resulting in abrupt variations of stresses and are to be kept clear of any form of openings which may affect their structural performances.

1.3.4 In general, superstructures or deckhouses will not be accepted as contributing to the global longitudinal or transverse strength of the craft. However, where it is proposed to include substantial, continuous stiffening members, special consideration will be given to their inclusion on submission of the designer's/Builder's calculations.

1.3.5 Where continuous deck longitudinals or deck girders are arranged above the strength deck, special consideration may be given to the inclusion of their sectional area in the calculation of the hull section modulus (Z). The lever is to be taken to a position corresponding to the depth of the longitudinal member above the moulded deckline at side amidships. Each such case will be individually considered.

1.3.6 Adequate transition brackets are to be fitted at the ends of effective continuous longitudinal strength members in the deck and bottom structures.

1.3.7 Scantlings of all continuous longitudinal members of the hull girder based on the minimum section stiffness requirements determined from *Pt 6, Ch 6, 2.2 Bending strength* are to be maintained within $0,4L_R$ amidships. However, in special cases, based on consideration of type of ship, hull form and loading conditions, the scantlings may be gradually reduced towards the ends of the $0,4L_R$ part, bearing in mind the desire not to inhibit the craft's loading and operational flexibility.

1.4 Openings

1.4.1 Deck openings having a length in the fore and aft directions exceeding $0,1B$ m or a breadth exceeding $0,05B$ m are in all cases to be deducted from the sectional areas used in the section modulus calculation.

1.4.2 Deck openings smaller than stated in 1.4.1, including manholes, need not be deducted provided they are isolated and the sum of their breadths or shadow area breadths (*see Pt 6, Ch 6, 1.4 Openings 1.4.3*) in one transverse section does not exceed $0,06\,(B_o - \Sigma b_o)$.

where

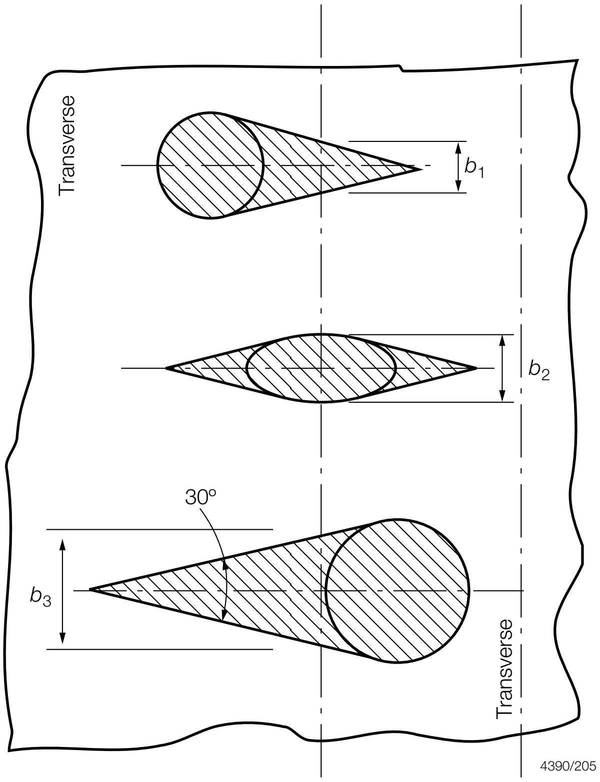
B_o = breadth of craft, in metres, at section considered

Σb_o = sum of breadths, in metres, of deductible openings

Where a large number of deck openings are proposed in any transverse space, special consideration will be required.

1.4.3 Where calculating deduction-free openings, the openings are assumed to have longitudinal extensions as shown by the shaded areas in *Figure 6.1.2 Isolated openings*. The shadow area is obtained by drawing two tangent lines to an opening angle of

30°. The section to be considered is to be perpendicular to the centreline of the ship and is to result in the maximum deduction in each transverse space.



Total equivalent breadth of small openings at xx = b_1 b_1 b_1

Figure 6.1.2 Isolated openings

1.4.4 Isolated openings in longitudinals or longitudinal girders need not be deducted if their depth does not exceed 25 per cent of the web depth or 75 mm, whichever is the lesser.

1.4.5 Openings are considered isolated if they are spaced not less than 1 m apart.

1.4.6 A reduction for drainage holes and scallops in beams and girders, etc. is not necessary so long as the original section stiffness at deck or keel is reduced by no more than 3,0 per cent.

1.5 Direct calculation procedure

1.5.1 In direct calculation procedures capable of deriving the wave induced loads on the craft, and hence the required modulus, account is to be taken of the craft's actual form and weight distribution.

1.5.2 Lloyd's Register's (hereinafter referred to as 'LR') direct calculation method involves derivation of response to regular waves by strip theory, short-term response to irregular waves using the sea spectrum concept, and long-term response predictions using statistical distributions of sea states. Other direct calculation methods submitted for approval are normally to contain these three elements and produce similar and consistent results when compared with LR's methods.

1.6 Approved calculation systems

1.6.1 Where the assumptions, method and procedures of a longitudinal strength calculation system have received general approval from LR, calculations using the system for a particular craft may be submitted.

1.7 Information required

1.7.1 In order that an assessment of the longitudinal strength requirements can be made, the following information is to be submitted, in LR's standard format where appropriate:

(a) General arrangement and capacity plan or list, showing details of the volume and position of centre of gravity of all tanks and compartments.
(b) Bonjean data, in the form of tables or curves, for at least 21 equally spaced stations along the hull. A lines plan and/or tables of offsets may also be required.
(c) Details of the calculated lightweight and its distribution.
(d) Details of the weights and centres of gravity of all deadweight items for each of the main loading conditions. It is recommended that this information be submitted in the form of a preliminary Loading Manual, to include the calculated still water and dynamic bending moments and shear forces.

1.8 Loading guidance information

1.8.1 Sufficient information is to be supplied to the Master of every craft to enable him to arrange loading in such a way as to avoid the creation of unacceptable stresses in the craft's structure.

■ *Section 2*
Hull girder strength for mono-hull craft

2.1 General

2.1.1 Longitudinal strength calculations are to be submitted for all craft with a Rule length, L_R, exceeding 50 m covering the range of load and ballast conditions proposed, in order to determine the required hull girder strength. Still water, static wave and dynamic bending moments and shear forces are to be calculated for both departure and arrival conditions.

2.1.2 For craft of ordinary hull form with a Rule length, L_R, less than 50 m, the minimum hull girder strength requirements are generally satisfied by scantlings obtained from local strength requirements. However longitudinal strength calculations may be required at LR's discretion, dependent upon the form, constructional arrangement and proposed loading.

2.1.3 Where the Rule length, L_R, of the craft exceeds 75 m, or for new designs of large, structurally complicated craft, the design loads and scantling determination formulae in this Chapter are to be supplemented by direct calculation and structural analysis by 3-D finite element methods. These supplementary calculations are to include the results of model tests and full scale measurement where available or required by LR. Full details of such methods and all assumptions and calculations, which are to be based on generally accepted theories, are to be submitted for appraisal.

2.2 Bending strength

2.2.1 The effective geometric properties of the midship section are to be calculated directly from the dimensions of the section using only the effective material elements which contribute to the global longitudinal strength irrespective of the grades of steel incorporated in the construction. For the purposes of this analysis an element may be of deck plating, longitudinal girder, inner bottom, etc. or other continuous member.

2.2.2 The contribution that higher tensile steel makes to the global strength is based upon the strain in that material in relation to the allowable strain in mild steel. Therefore, the maximum permissible hull vertical bending stress, σ_p, for the design analysis is not to be taken greater than that determined from the following:

$$\sigma_{p(HTS)} = \sigma_{p(MS)} \frac{\bar{y}_{(HTS)}}{\bar{y}_{(MS)}}$$

where

σ_p = is as defined in *Pt 6, Ch 6, 2.2 Bending strength 2.2.3*

$\bar{y}_{(HTS)}$ = the maximum distance, in metres, above or below the neutral axis of the hull cross-section to any effective higher tensile steel element contributing to global longitudinal strength.

where

$\overline{y}_{(MS)}$ = the maximum distance, in metres, above or below the neutral axis of the hull cross-section to any effective mild steel element contributing to global longitudinal strength.

2.2.3 The longitudinal strength of craft

with

$\frac{V}{\sqrt{L_{WL}}} \geq 3,0$ is to satisfy both the following criteria:

$\sigma_k + \sigma_l + \sigma_t < 1,2\ \sigma_P$ and

$\sigma_d < \sigma_P$

where

σ_P = maximum permissible hull vertical bending stress, in N/mm^2 and is not to be taken greater than that determined from *Pt 6, Ch 6, 2.2 Bending strength 2.2.2*

= $f_{\sigma gH}\ \sigma_s$ or the value determined from *Pt 6, Ch 6, 2.2 Bending strength 2.2.2*, whichever is the lesser

$f_{\sigma gH}$ = limiting hull bending stress coefficient taken from *Table 7.3.2 Limiting stress coefficients for global loading* in Chapter 7

L_{WL} is as defined in *Pt 3, Ch 1, 6.2 Principal particulars 6.2.5*

σ_k, $\sigma\ l$, σ_t and σ_d are given in *Table 6.2.1 Longitudinal component stresses*

σ_s is as defined in *Pt 6, Ch 6, 1.2 Symbols and definitions 1.2.1*.

Table 6.2.1 Longitudinal component stresses

Component stress type	Nominal stress (N/mm^2)
Hull girder bending stress at strength deck amidships	$\sigma_d = \frac{M_R}{1000 Z_d}$
Hull girder bending stress at keel amidships	$\sigma_k = \frac{M_R}{1000 Z_k}$
Actual stress in bottom longitudinals amidships due to design pressure load	$\sigma_l = \frac{p_s s l_e^2}{12 Z_l}$
Actual stress in bottom plating amidships due to design pressure load	$\sigma_t = 0,34 P_t \left(\frac{\beta s}{t_p}\right)^2 \times 10^{-3}$

Symbols and definitions
M_R = design longitudinal midship bending moment, in kNm, given in *Pt 5, Ch 5, 2 Hull girder load criteria for mono-hull craft*
p_s = additional effective pressure loading, in kN/m^2, on bottom longitudinals from global dynamic load model, given in *Pt 5, Ch 5, 2.6 Dynamic bending moments and associated shear forces 2.6.3*
P_t = additional effective pressure loading, in kN/m^2, on bottom plating from global dynamic load model, given in *Pt 5, Ch 5, 2.6 Dynamic bending moments and associated shear forces 2.6.4*
Z_d = actual section modulus at deck, in m^3
Z_k = actual section modulus at keel, in m^3
Z_l = actual section modulus of bottom longitudinal stiffener amidships, in cm^3
s, l_e, β and t_p are as defined in *Pt 6, Ch 6, 1.2 Symbols and definitions*.

2.2.4 The longitudinal strength of craft

where

$\frac{V}{\sqrt{L_{WL}}} < 3{,}0$ is to satisfy both the following criteria:

$\sigma_k < \sigma_P$

$\sigma_d < \sigma_P$

where σ_p is as defined in *Pt 6, Ch 6, 2.2 Bending strength 2.2.3*

σ_k and σ_d are given in *Table 6.2.1 Longitudinal component stresses*

L_{WL} is as defined in *Pt 3, Ch 1, 6.2 Principal particulars 6.2.5*.

2.3 Minimum hull section modulus

2.3.1 For patrol craft in Service Group G6, the hull midship modulus about the transverse neutral axis, at the deck or the keel, is to be not less than:

$$Z_{min} = k_l L_f L_R^2 B_{WL} \left(C_b + 0,7\right) 10^{-6} \text{m}^3$$

where

k_L = is the higher tensile steel factor

$$= \frac{235}{\sigma_\alpha \eta_{HTS}}$$

where

σ_α = is the specified minimum yield stress in N/mm^2, as defined in *Pt 6, Ch 2, 2.4 Mechanical properties for design 2.4.3*

η_{HTS} = is the higher tensile steel concentration factor as defined in *Pt 6, Ch 2, 2.4 Mechanical properties for design 2.4.3*

L_R and C_b = are as given in *Pt 5, Ch 5, 2.2 Vertical wave bending moments*

C_b = to be taken not less than 0,6

L_f = are as given in *Pt 5, Ch 5, 2.2 Vertical wave bending moments 2.2.1*

B_{WL} = maximum breadth at the design waterline, in metres.

2.4 Shear strength

2.4.1 The shear strength of the craft at any position along its length is to satisfy the following criterion:

$$\frac{Q_R}{A_\tau} 10^{-3} \le \tau_p$$

where

Q_R = design hull shear force at any section along the Rule length, L_R, in kN determined from *Pt 5, Ch 5, 5 Design criteria and load combinations*

$A\tau$ = shear area of transverse section, in m^2, is to be taken as the effective net sectional area of the shell plating and longitudinal bulkheads after deductions for openings. For longitudinal strength members which are inclined to the vertical, the area of the member to be included in the calculation is to be based on the area projected onto the vertical plane, *see Figure 6.2.1 Effective shear area*

τ_p = maximum permissible mean shear stress, in N/mm^2

= $f_{\tau gH}\, \tau_s$

$f_{\tau gH}$ = limiting hull shear stress coefficient taken from *Table 7.3.2 Limiting stress coefficients for global loading* in Chapter 7.

τ_s is as defined in *Pt 6, Ch 6, 1.2 Symbols and definitions 1.2.1*.

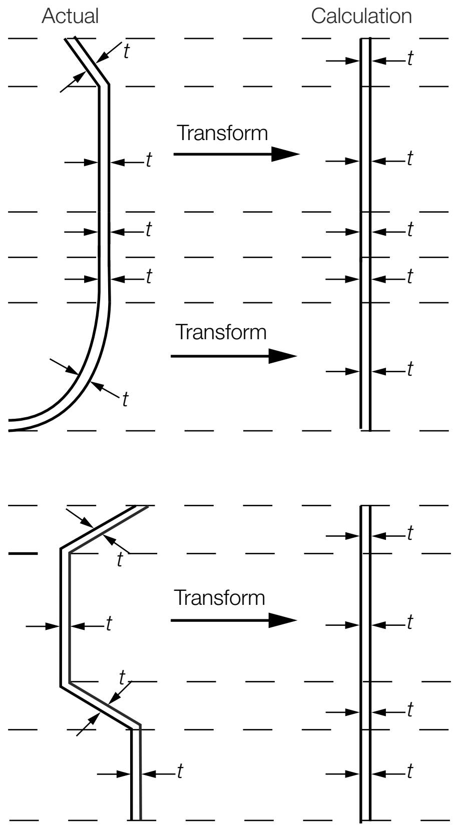


Figure 6.2.1 Effective shear area

2.5 Torsional strength

2.5.1 Torsional stresses are typically small for monohulls of ordinary form of Rule length, L_R, less than 75 m and can generally be ignored.

2.5.2 The calculation of torsional stresses and/or deflections may be required when considering craft with large deck openings, unusual form or proportions. Calculations may in general be required to be carried out using a direct calculation procedure. Such calculations are to be submitted in accordance with *Pt 6, Ch 6, 1.5 Direct calculation procedure*.

2.6 Superstructures global strength

2.6.1 Where the side walls of superstructures are aligned with the side shell and these side walls are fully plated with scantlings as for side shell, the effect of the superstructure in global strength can be estimated from paragraphs *Pt 6, Ch 6, 2.6 Superstructures global strength 2.6.2* to *Pt 6, Ch 6, 2.6 Superstructures global strength 2.6.6*. In case there are openings in the side walls that would affect the connection of the superstructure deck with the hull, or when the side walls are not in-line with the side shell, the effectiveness of the superstructure in global strength is to be determined by direct calculation.

2.6.2 The effectiveness of the superstructure in absorbing hull girder bending loads is to be established where the first tier of the superstructure extends within 0,4*L* amidships and where:

$$l_1 > b_1 + 3h_1$$

where

l_1 = length of first tier, in metres

b_1 = breadth of first tier, in metres

h_1 = 'tween deck height of first tier, in metres

2.6.3 For superstructures with one or two tiers extending outboard to the craft's side shell, the effectiveness in absorbing hull girder bending loads in the uppermost effective tier may be assessed by the following factor:

$$\eta_s = 7\left[(\epsilon - 5)\gamma^4 + 94(5 - \epsilon)\gamma^3 + 2800(\epsilon - 5,8)\gamma^2 + 27660(9 - \epsilon)\gamma\right] f(\lambda, N) \times 10^{-7}$$

where

$f(\lambda, N=1)$ = 1

$f(\lambda, N=2)$ = $0,90\lambda^3 - 2,17\lambda^2 + 1,73\lambda + 0,50$

and

N = 1 if $l_2 < 0,7\, l_1$

= 2 if $l_2 \geq 0,7\, l_1$

λ = $\dfrac{l_w}{L_R}$ or 1, whichever is less

ε = $\dfrac{b_1}{h_1}$ or 5, whichever is less

γ = $\dfrac{l_w}{h_1}$ or 25, whichever is less

l_w = l_1 for N = 1

= $\dfrac{(2l_1 + l_2)}{3}$ for N = 2

L_R = as defined in *Pt 6, Ch 6, 1.2 Symbols and definitions 1.2.1*, in metres

l_1, b_1, h_1 = as defined in *Pt 6, Ch 6, 2.5 Torsional strength 2.5.1*, in metres

and

l_2 = length of second tier, in metres.

2.6.4 The hull girder compressive bending stress σ_L, in the uppermost effective tier at side may be derived according to the following formula:

$$\sigma_L = \eta_s \frac{M_R}{1000 Z_{100}} \text{ N/mm}^2$$

where

M_R = hull girder bending moment at midships due to sagging as determined in *Pt 5, Ch 5, 5 Design criteria and load combinations*, in kNm

Z_{100} = section modulus at uppermost effective tier of hull and effective tiers, assuming tiers to be 100 per cent effective, in m^3

η_s = as defined in *Pt 6, Ch 6, 2.6 Superstructures global strength 2.6.3*

2.6.5 The compressive stress, σ_L, in the uppermost effective tier at side is to be checked against buckling in accordance with *Pt 6, Ch 7, 4 Buckling control*.

2.6.6 The uppermost effective tier may need to fulfil the requirements for strength deck when the following applies:

$$\eta_s > \left(1 + \frac{Z_0 h}{I_{100}}\right)^{-1}$$

where

η_s = as defined in *Pt 6, Ch 6, 2.6 Superstructures global strength 2.6.3*

Z_0 = section modulus of hull only at hull upper deck, in m^3

I_{100} = moment of inertia of hull and effective tiers, assuming tiers to be 100 per cent effective, in m^4

h = height from hull upper deck to uppermost effective tier, in metres.

2.6.7 The deformation of large openings in side walls of superstructures is to be investigated. They should not exceed the deformation limit of the closing appliances.

■ *Section 3*
Additional hull girder strength requirements for multi-hull craft

3.1 General

3.1.1 Except as otherwise specified within this Section, the global strength requirements for multi-hull craft are to comply with *Pt 6, Ch 6, 2 Hull girder strength for mono-hull craft*.

3.1.2 Longitudinal strength calculations are to be submitted for all craft with a length, L_R, exceeding 40 m covering the range of load and ballast conditions proposed, in order to determine the required hull girder strength. Still water, static wave and dynamic bending moments and shear forces are to be calculated for both departure and arrival conditions.

3.1.3 For craft of ordinary hull form length with a Rule length, L_R, less than 40 metres, the minimum hull girder strength requirements are generally satisfied by scantlings obtained from local strength requirements. However longitudinal strength calculations may be required at LR's discretion, dependent upon the proposed loading.

3.1.4 Where the length, L_R, of the craft exceeds 60 m, or for new designs of large, structurally complicated craft, the design loads and scantling determination formulae in this Chapter are to be supplemented by direct calculation and structural analysis by 3-D finite element methods. These supplementary calculations are to include the results of model tests and full scale measurement where available or required by LR. Full details of such methods and all assumptions and calculations, which are to be based on generally accepted theories, are to be submitted for appraisal.

3.1.5 The strength deck plating in way of the cross-deck structure, the wet-deck plating, longitudinal bulkheads and girders, and other continuous members may be included in the determination of the midship section stiffness.

3.1.6 Special consideration will be given to the global strength requirements for craft with more than two hulls linked by cross-deck structure.

3.2 Hull longitudinal bending strength

3.2.1 The requirements of *Pt 6, Ch 6, 2.2 Bending strength* are in general to be complied with, using the appropriate design bending moment and effective pressure loadings applicable to multi-hull craft, as determined from *Pt 5, Ch 5, 5 Design criteria and load combinations*.

3.3 Hull shear strength

3.3.1 The requirements of *Pt 6, Ch 6, 2.3 Minimum hull section modulus* are to be complied with so far as they are applicable.

3.4 Torsional strength

3.4.1 Where a craft is of unusual form or novel construction, or at the discretion of LR, the torsional stress is to be determined by direct calculation methods using the twin hull torsional connecting moment as defined in *Pt 5, Ch 5, 5 Design criteria and load combinations*. Such calculations are to be submitted in accordance with *Pt 6, Ch 6, 1.5 Direct calculation procedure*.

3.5 Strength of cross-deck structures

3.5.1 Design loads to be applied for scantling calculations are transverse vertical bending moment and shear force, twin hull torsional connecting moment, external pressure load and appropriate internal loads as defined in *Pt 5 Design and Load Criteria*.

3.5.2 The primary stiffening members of the cross-deck structure are to provide sufficient strength to satisfy the stress criteria given in *Table 6.3.1 Primary member stress criteria*.

Table 6.3.1 Primary member stress criteria

Stress type	Component stresses	Allowable stress level (N/mm^2)
Total direct stress, σ_P	$\sigma_P = \sigma_{MB} + \sigma_{MT} + \sigma_d$	$f_{\sigma gV}\sigma_S$
Total shear stress, τ_P	$\tau_P = \tau_T + \tau_{MBT} + \tau_{MT}$	$f_{\tau gV}\ \tau_S$
Equivalent stress, σ_{eq}	$\sigma_{eq} = \sqrt{\sigma^2 + 3\tau^2}$	1,2 $f_{\sigma eg}\sigma_S$
Symbols and definitions		
σ_{MB}, σ_{MT}, τ_T, $\tau_{MBT}\sigma_d$ and τ_{MT} are component stresses, in N/mm^2, to be taken from *Table 6.3.2 Cross-deck component stresses for designs complying with 3.5.3*. $f_{\sigma gV}$, $f_{\tau gV}$ and $f_{\sigma eg}$ are limiting stress coefficients for cross-deck structures to be taken from *Table 7.3.2 Limiting stress coefficients for global loading* in Chapter 7. σ_S and τ_S are defined in*Pt 6, Ch 6, 1.2 Symbols and definitions*.		

3.5.3 The component nominal stresses may be determined in accordance with *Table 6.3.2 Cross-deck component stresses for designs complying with 3.5.3* in the case where the cross-deck is formed by transverse primary stiffeners or bulkheads and the following assumptions are taken:

(a) The cross-deck is symmetrical forward and aft of a transverse axis at its half length.
(b) Primary stiffeners having the same scantlings and spacing.

Table 6.3.2 Cross-deck component stresses for designs complying with 3.5.3

Component stress type	Nominal stress (N/mm^2)
Hull girder bending stress at strength deck amidships, *see Table 6.2.1 Longitudinal component stresses*	$\sigma_d = f_{MR} \dfrac{M_R}{1000 Z_d}$
Stress induced by the transverse bending moment M_B, as defined in *Pt 5, Ch 5, 5 Design criteria and load combinations*	$\sigma_{MB} = f_{MB} \dfrac{M_B}{n Z} 10^3$
Stress induced by the torsional moment M_T, as defined in *Pt 5, Ch 5, 5 Design criteria and load combinations*	$\sigma_{MT} = f_{MT} \dfrac{3 x_H M_T}{n(n+1) s_p Z} 10^3$
Shear stress induced by the vertical shear force Q_T, as defined in *Pt 5, Ch 5, 5 Design criteria and load combinations*	$\tau_T = f_{MB} \dfrac{5 Q_T}{n A_w}$
Bending shear stress induced by the torsional moment M_T, as defined in *Pt 5, Ch 5, 5 Design criteria and load combinations*	$\tau_{MBT} = f_{MT} \dfrac{60 M_T}{n(n+1) s_p A_w}$
Shear stress induced by the torsional moment M_T, as defined in *Pt 5, Ch 5, 5 Design criteria and load combinations*	$\tau_M = f_{MT} \dfrac{46 K x_H^2 M_T}{n\left(n^2+1\right) s_p^2 I_y} 10^3$

Symbols and definitions
Q_T = vertical shear force, in kN, as determined from *Pt 5, Ch 5, 5 Design criteria and load combinations*
M_B = transverse bending moment in kNm, as determined from *Pt 5, Ch 5, 5 Design criteria and load combinations*
M_T = torsional moment in kNm, as determined from *Pt 5, Ch 5, 5 Design criteria and load combinations*
n = total number of transverse primary stiffeners or bulkheads
A_W = stiffener web area, cm^2
Z = primary stiffeners sections section modulus, in cm^3
s_p = stiffener spacing, in metres
I_y = moment of inertia of stiffener, cm^4
x_H = transverse distance between the centre of the two hulls, in metres
κ = t_f, for symmetrical I-section, in mm
= $b_b\, h/(b_b + h)$, for constant thickness box sections, in mm
σ_{MB} = stress induced by the transverse bending moment M_B, as defined in *Pt 5, Ch 5, 5 Design criteria and load combinations*, in N/mm^2
σ_{MT} = stress induced by the torsional moment M_T, as defined in *Pt 5, Ch 5, 5 Design criteria and load combinations*, in N/mm^2
τ_T = shear stress induced by the vertical shear force Q_T, as defined in *Pt 5, Ch 5, 5 Design criteria and load combinations*, in N/mm^2
τ_{MBT} = bending shear stress induced by the torsional moment M_T, as defined in *Pt 5, Ch 5, 5 Design criteria and load combinations*, in N/mm^2
τ_{MT} = shear stress induced by the torsional moment M_T, as defined in *Pt 5, Ch 5, 5 Design criteria and load combinations*, in N/mm^2
t_f = face plate thickness, in mm
b_b = breadth of box section, in mm
h_b = height of box section, in mm
f_{MR}, f_{MB} and f_{MT} are load combination factors reflecting the portions of each component global design load, M_R, Q_T, M_B and M_T, corresponding to the most severe load combinations. The most severe load combinations are the combinations of loads resulting in the maximum bending, shear and effective stress, respectively. The assessment of these load combinations need to take due consideration for the component load magnitude variation with wave heading and also the phasing in time between them. Generally, f_{MR}, f_{MB} and f_{MT} are to be taken as indicated in *Table 6.3.3 Load combination factors*.

Table 6.3.3 Load combination factors

Heading	Factors		
	f_{MB}	f_{MR}	f_{MT}
Head sea	0,1	1,0	0,1

Beam sea	1,0	0,1	0,2
Quartering sea	0,1	0,4	1,0

3.5.4 Other cross-deck designs subjected to global transverse loads will require a two-dimensional grillage analysis to be performed to demonstrate compliance with *Pt 6, Ch 6, 3.5 Strength of cross-deck structures 3.5.2*.

3.5.5 Section properties are to be calculated using an effective breadth of plating to be determined in accordance with *Pt 6, Ch 3, 1.11 Other materials*.

3.5.6 Where primary stiffening members support areas of plating of the extruded plank type, or the floating frame system is used, the effect of the plating attached to the secondary stiffening members is to be ignored when determining the global section modulus requirements.

3.6 Grillage structures

3.6.1 For complex girder systems, a complete structural analysis using numerical methods may be required to be performed to demonstrate that the stress levels are acceptable when subjected to the most severe and realistic combination of loading conditions intended.

3.6.2 In general, the transverse and vertical girders, bottom and side structures, bridge structure, deck structures and any other parts of the craft which LR considers critical to the craft's structural integrity are to be included in the numerical modelling of the craft.

3.7 Analysis techniques

3.7.1 General or special purpose computer programs or any other analytical techniques may be used provided that the effects of bending, shear, axial and torsion are properly accounted for and the theory and idealisation used can be justified.

3.7.2 In general, grillages consisting of slender girders may be idealised as frames based on beam theory provided proper account of the variations of geometric properties is taken. For cases where such an assumption is not applicable, finite element analysis or equivalent methods may have to be used.

3.7.3 Analysis of the cross-deck structures with regard to impact loads due to slamming may have to be carried out using advanced structural analysis techniques.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull and multi-hull craft of steel construction as defined in *Pt 6, Ch 1, 1.1 General*.

1.2 General

1.2.1 The failure modes criteria contained within this Chapter are to be used in the formulae from the preceding Chapters to determine the scantling requirements. In addition, they are to be used when direct calculation methods are proposed as an alternative.

1.3 Symbols and definitions

1.3.1 The symbols and definitions applicable to this Chapter are defined below or in the appropriate Section.

1.3.2 The slamming zone area referred to in this Chapter is defined as the region where the operational non-displacement mode pressures exceed the operational displacement mode pressures.

1.4 Direct calculations

1.4.1 Where direct calculations are proposed, the requirements of *Pt 3, Ch 1, 2 Direct calculations* are to be complied with.

1.4.2 In addition, with the agreement of Lloyd's Register (hereinafter referred to as 'LR'), tests may be conducted to demonstrate the actual response of the structure and the results verified against the failure mode criteria in this Chapter.

■ *Section 2* Deflection control

2.1 General

2.1.1 The limiting deflection requirements for plate panels and stiffening members are given in terms of limiting deflection coefficient, *see Table 7.2.1 Limiting deflection ratio*. The coefficient equates to a span/deflection ratio, f_δ, in consistent units.

Table 7.2.1 Limiting deflection ratio

Item	Deflection ratios, f_δ
Bottom structure:	

	• secondary stiffening • primary girders and web frames	800 1000
Side structure:		
	• secondary stiffening • primary girders and web frames	800 1000
Main/strength deck structures:		
	• secondary stiffening • primary girders and web frames • hatch covers	1000 1250 1250
Superstructures/deckhouses stiffeners:		
(a) Generally	• secondary • primary	600 750
(b) Coachroof	• secondary • primary	800 1000
(c) House top	• secondary • primary	600 600
Lower/inner decks and house top subject to personnel loading:		
	• secondary members • primary members	800 1000
Deep tank structures:		
Stiffeners	• secondary members • primary members	1000 1250
Watertight bulkhead structures:		
Stiffeners	• secondary members • primary members	600 750
Multi-hull cross-deck structures:		
Stiffeners	• secondary members • primary members	800 1000
Vehicle deck structures:		
Stiffeners	• secondary members • primary members	1000 1250
Helicopter/flight decks:		
Stiffeners	• secondary members • primary members	1000 1250
Note Where significant curvature exists over the span of the stiffener or breadth of the panel, the allowable deflections will be specially considered.		

Section 3
Stress control

3.1 General

3.1.1 The nominal limiting stress requirements for plating and primary and secondary stiffening members subject to local loading conditions are given in terms of limiting stress coefficients, *see Table 7.3.1 Limiting stress coefficient for local loading* . The coefficients are expressed as a proportion of the yield stress of the material.

3.1.2 The limiting stress coefficients for structural elements subject to global loading conditions are given in *Table 7.3.2 Limiting stress coefficients for global loading*.

3.1.3 In the determination of the magnitude of the equivalent stress, σ_{eq}, it is assumed that the stresses are combined using the following formula:

$$\sigma_{eq} = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x \sigma_y + 3\tau^2}$$

where

σ_x = direct stress in the x direction

σ_y = direct stress in the y direction

τ = shear stress in the xy plane

Table 7.3.1 Limiting stress coefficient for local loading

Item		Limiting stress coefficient		
		Bending f_σ	Shear f_τ	Equivalent f_e
Shell envelope:				
(a) Bottom shell plating:	• slamming zone	0,85	-	-
	• elsewhere	0,75	-	-
(b) Side shell plating:	• slamming zone	0,85	-	-
	• elsewhere	0,75	-	-
(c) Keel		0,75	-	-
Bottom structure:				
(a) Secondary stiffening:	• slamming zone	0,75	0,75	-
	• elsewhere	0,65	0,65	-
(b) Primary girders and web frames		0,65	0,65	0,75
(c) Engine girders		0,55	0,55	0,75
Side structure:				
(a) Secondary stiffening:	• slamming zone	0,75	0,75	-
	• elsewhere	0,65	0,65	-
(b) Primary girders and web frames		0,65	0,65	0,75

Bow doors:			
(a) Plating	0,65	-	-
(b) Secondary stiffening	0,51	0,433	-
(c) Primary stiffening	0,51	0,34	0,64
Main/strength deck plating and stiffeners:			
(a) Plating	0,75	-	-
(b) Secondary stiffening	0,65	0,65	-
(c) Primary girders and web frame	0,65	0,65	0,75
(d) Hatch covers	0,55	0,55	0,64
Superstructures/deckhouses:			
(a) Deckhouse front 1st tier: • plating	0,65	-	-
• stiffening	0,60	0,60	-
(b) Deckhouse front upper tiers: • plating	0,75	-	-
• stiffening	0,65	0,65	-
(c) Deckhouse aft and sides: • plating	0,75	-	-
• stiffening	0,75	0,75	-
(d) Coachroof: • plating	0,65	-	-
• stiffening	0,65	0,65	-
(e) House top: • plating	0,75	-	-
• stiffening	0,75	0,75	-
(f) Lower/inner decks and house top subject to personnel loading:			-
• plating	0,75	-	-
• stiffening	0,60	0,60	-
Bulkheads:			
(a) Watertight bulkhead: • plating	1,0	-	-
• secondary stiffening	0,95	0,95	-
• primary stiffening	0,90	0,90	1,0
(b) Watertight bulkhead doors	0,825	0,825	-
(c) Structure supporting watertight doors	0,80	0,80	-
(d) Minor bulkheads: • plating	0,65	-	-
• secondary stiffening	0,65	0,65	-

	• primary stiffening	0,65	0,65	0,75
(e) Deep tank bulkheads:	• plating	0,65	-	-
	• secondary stiffening	0,65	0,65	-
	• primary stiffening	0,75	0,75	-
Multi-hull cross-deck structure:				
(a) Plating:	• slamming zone	0,85	-	-
	• elsewhere	0,75	-	-
(b) Secondary stiffening:	• slamming zone	0,75	0,75	-
	• elsewhere	0,65	0,65	-
(c) Primary stiffening		0,65	0,65	0,75
Vehicle deck:				
(a) Plating		0,6	-	-
(b) Secondary stiffening		0,425	0,425	-
(c) Primary stiffening		0,525	0,525	0,75
Helicopter/flight decks:				
(a) Normal usage:	• plating	0,65	-	-
	• secondary stiffening	0,75	0,75	-
	• primary stiffening	0,625	0,625	0,6
(b) Emergency landing:	• plating	0,75	-	-
	• secondary stiffening	1,0	1,0	-
	• primary stiffening	0,825	0,825	0,9
(c) Crane pedestal/foundation structural elements		0,7	0,70	0,75

Table 7.3.2 Limiting stress coefficients for global loading

Operational mode of craft	Limiting stress coefficient					
	Hull girder			Cross-deck		
	Bending $f_{\sigma gH}$	Shear $f_{\tau gH}$	Equivalent $f_{\sigma eg}$	Bending $f_{\sigma gV}$	Shear $f_{\tau gV}$	Equivalent $f_{\sigma eg}$
$\Gamma \geq 3,0$ or $\Delta \leq 0,04(L_R B)^{1,5}$	$0,80\eta_{HTS}$	$0,80\eta_{HTS}$	$0,825\eta_{HTS}$	$0,80\eta_{HTS}$	$0,80\eta_{HTS}$	$0,825\eta_{HTS}$

$\Gamma < 3{,}0$ or $\Delta > 0{,}04(L_R B)^{1,5}$	$0{,}72\eta_{HTS}$	$0{,}72\eta_{HTS}$	$0{,}75\eta_{HTS}$	$0{,}72\eta_{HTS}$	$0{,}72\eta_{HTS}$	$0{,}75\eta_{HTS}$

Note

$f_{\sigma gH}$ = limiting hull bending stress coefficient

$f_{\tau gH}$ = limiting hull shear stress coefficient

$f_{\sigma gV}$ = limiting cross-deck bending stress coefficient.

$f_{\tau gV}$ = limiting cross-deck shear stress coefficient

$f_{\sigma eg}$ = limiting equivalent stress coefficient

Δ is the displacement as defined in *Pt 5, Ch 2, 2 Definitions and symbols*. Γ is the Taylor Quotient as defined in *Pt 5, Ch 2, 2.1 Parameters to be used for the determination of load and design criteria 2.1.16*. L_R and B are as defined in *Pt 3, Ch 1, 6.2 Principal particulars*. η_{HTS} is as defined in *Pt 6, Ch 2, 2.4 Mechanical properties for design 2.4.3*.

■ *Section 4*
Buckling control

4.1 General

4.1.1 This Section contains the requirements for buckling control of plate panels subject to in-plane compressive and/or shear stresses and buckling control of primary and secondary stiffening members subject to axial compressive and shear stresses.

4.1.2 The requirements for buckling control of plate panels are contained in *Pt 6, Ch 7, 4.3 Plate panel buckling requirements*. The requirements for secondary stiffening members are contained in *Pt 6, Ch 7, 4.7 Secondary stiffening in direction of compression* and *Pt 6, Ch 7, 4.8 Secondary stiffening perpendicular to direction of compression*. The requirements for primary members are contained in *Pt 6, Ch 7, 4.9 Buckling of primary members* and *Pt 6, Ch 7, 4.10 Shear buckling of girder webs*.

4.1.3 In general all areas of the structure are to meet the buckling strength requirements for the design stresses. The design stresses are to be taken as follows:

(a) Global hull girder bending and shear stresses given in *Pt 6, Ch 6 Hull Girder Strength*, but not including stresses σ_l and σ_t as defined in *Table 6.2.1 Longitudinal component stresses* in *Pt 6, Ch 6 Hull Girder Strength*.
(b) Stresses from local compressive loads.

4.1.4 The buckling requirements are to be met using the net scantlings, hence any additional thickness for corrosion margin or Owners extra is not included in scantlings used to assess the buckling performance.

4.2 Symbols

4.2.1 The symbols used in this Section are defined below and in the appropriate sub-Section:

t_p = thickness of plating, in mm

A_R = panel aspect ratio

$= \dfrac{a}{b}$

a = panel length, i.e. parallel to direction of compressive stress being considered, in mm

b = panel breadth i.e. perpendicular to direction of compressive stress being considered, in mm

S_p = span of primary members, in metres

σ_o = specified minimum yield strength of the material, in N/mm^2

σ_e = elastic compressive buckling stress, in N/mm^2

σ_c = critical compressive buckling stress, including the effects of plasticity where appropriate, in N/mm^2

τ_o = specified minimum yield shear stress of material, in N/mm^2

= $\dfrac{\sigma_o}{\sqrt{3}}$ N/mm^2

E = modulus of elasticity of material, in N/mm^2

τ_e = elastic shear buckling stress, in N/mm^2

τ_c = critical shear buckling stress, in N/mm^2

b_{eb} = lesser of $1{,}9 t_p \sqrt{\dfrac{E}{\sigma_o}}$ or $0{,}8b$ mm

A_{te} = cross-sectional area of secondary stiffener, in cm^2, including an effective breadth of attached plating, b_{eb}

s = length of shorter edge of plate panel, in mm (typically the spacing of secondary stiffeners)

l = length of longer edge of plate panel, in metres.

S = spacing of primary member, in metres (measured in direction of compression).

4.3 Plate panel buckling requirements

4.3.1 This Section gives methods for evaluating the buckling strength of plate panels subjected to the following load fields:

(a) uni-axial compressive loads;
(b) shear loads;
(c) bi-axial compressive loads;
(d) uni-axial compressive loads and shear loads;
(e) bi-axial compressive loads and shear loads.

4.3.2 The plate panel buckling requirements will be satisfied if the buckling interaction equations given in *Table 7.4.2 Plate panel buckling requirements* for the above load fields are complied with.

4.3.3 The critical compressive buckling stresses and critical shear buckling stresses required for *Table 7.4.2 Plate panel buckling requirements* are to be derived in accordance with *Pt 6, Ch 7, 4.4 Derivation of the buckling stress for plate panels*.

4.3.4 The buckling factors of safety λ_σ and λ_τ required by *Table 7.4.2 Plate panel buckling requirements* are given in *Table 7.4.4 Buckling factor of safety* for the structural member concerned.

4.3.5 For all structural members which contribute to the hull girder strength, the plate panel buckling requirements for uni-axial compressive loads, *Table 7.4.2 Plate panel buckling requirements*, and shear loads, *Table 7.4.2 Plate panel buckling requirements* are to be complied with.

4.3.6 In addition to *Pt 6, Ch 7, 4.3 Plate panel buckling requirements 4.3.5*, structural members which are subjected to local compressive loads and/or shear loads are to be verified using the plate panel buckling requirements in *Table 7.4.2 Plate panel buckling requirements*.

4.3.7 However, where some members of the structure have been designed such that elastic buckling of the plate panel between the stiffeners is allowable, then the requirements of *Pt 6, Ch 7, 4.5 Additional requirements for plate panels which buckle elastically* must be applied to the buckling analysis of the stiffeners supporting the plating. In addition, panels which do not satisfy the panel buckling requirements must be indicated on the appropriate drawing and the effect of these panels not being effective in transmitting compressive loads taken into account for the hull girder strength calculation.

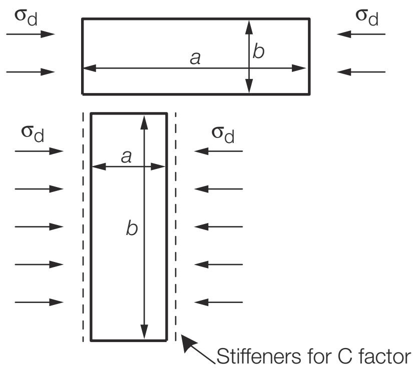
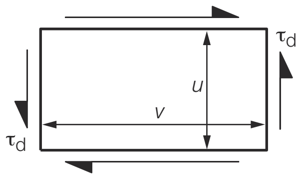
4.3.8 In general the plate panel buckling requirements for more complex load fields, *see Pt 6, Ch 7, 4.3 Plate panel buckling requirements 4.3.1.(c)*, *Pt 6, Ch 7, 4.3 Plate panel buckling requirements 4.3.1.(d)* and *Pt 6, Ch 7, 4.3 Plate panel buckling requirements 4.3.1.(e)*, are to be complied with. Where this is not possible, due to elastic buckling of the panel, then the critical buckling stress, σ_χ, may be based on the ultimate collapse strength of the plating, σ_υ from *Pt 6, Ch 7, 4.5 Additional requirements for plate panels which buckle elastically 4.5.4*, instead of the elastic buckling stress, σ_ε, derived in *Pt 6, Ch 7, 4.3 Plate panel buckling requirements 4.3.5*. In addition, the requirements of *Pt 6, Ch 7, 4.5 Additional requirements for plate panels which buckle elastically* are to be met for the supporting secondary stiffeners and primary members.

4.4 Derivation of the buckling stress for plate panels

4.4.1 The critical compressive buckling stress, σ_C for a plate panel subjected to uni-axial in-plane compressive loads is to be derived in accordance with *Table 7.4.1 Buckling stress of plate panels*.

4.4.2 The critical shear buckling stress, τ_C, for a plate panel subjected to pure in-plane shear load is to be derived in accordance with *Table 7.4.1 Buckling stress of plate panels*.

Table 7.4.1 Buckling stress of plate panels

Mode	Elastic buckling stress, N/mm^2, *see* Note 1	
(a) Uni-axial compression: (i) Long narrow panels, loaded on the narrow edge (ii) Short broad panels,	$A_R \geq 1$ $\sigma_e = 3{,}623\phi E\left(\frac{t_p}{b}\right)^2$ $A_R < 1$ $\sigma_e = 0{,}9C\phi\left(\frac{b}{a}+\frac{a}{b}\right)^2 E\left(\frac{t_p}{b}\right)^2$	
(b) Pure shear:	$\tau_e = 3{,}62\left(1{,}335+\left(\frac{u}{v}\right)^2\right)E\left(\frac{t_p}{u}\right)^2$ *See* Note 2	

Note 1. The critical buckling stresses, in N/mm^2, are to be derived from the elastic buckling stresses as follows:

$$\sigma_C = \sigma_e \text{ when } \sigma_e < \frac{\sigma_o}{2}$$

$$= \sigma_o\left(1-\frac{\sigma_o}{4\sigma_e}\right) \text{ when } \sigma_e \geq \frac{\sigma_o}{2}$$

$$\tau_C = \tau_e \text{ when } \tau_e < \frac{\tau_o}{2}$$

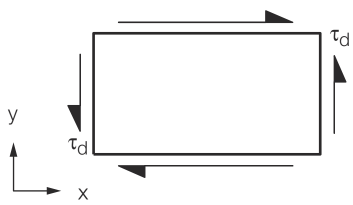
$$= \tau_o\left(1-\frac{\tau_o}{4\tau_e}\right) \text{ when } \tau_e \geq \frac{\tau_o}{2}$$

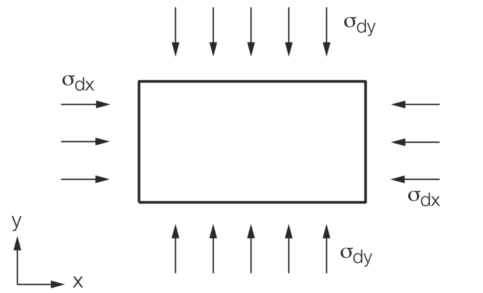
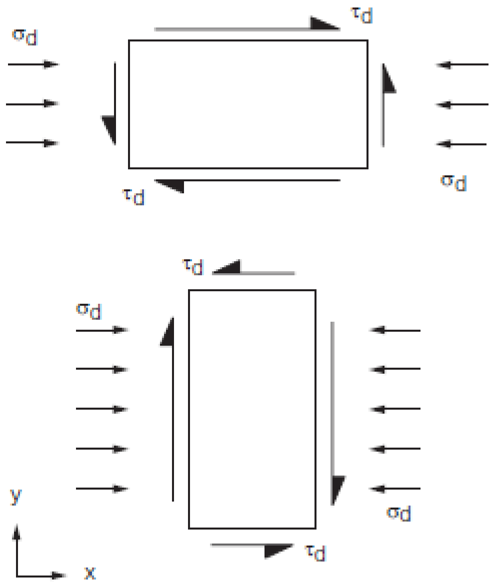
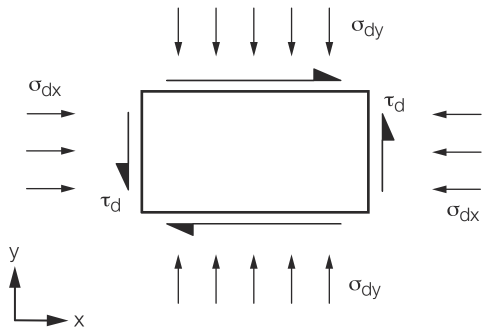
σ_C is defined in *Pt 6, Ch 7, 4.2 Symbols 4.2.1*
σ_o is defined in *Pt 6, Ch 7, 4.2 Symbols 4.2.1*
τ_C is defined in *Pt 6, Ch 7, 4.2 Symbols 4.2.1*
τ_o is defined in *Pt 6, Ch 7, 4.2 Symbols 4.2.1*

Note 2. *u* is to be the minimum dimension

Symbols and definitions
A_R = panel aspect ratio, *see Pt 6, Ch 7, 4.2 Symbols 4.2.1*
σ_e = elastic compressive buckling stress, in N/mm^2
τ_e = elastic shear buckling stress, in N/mm^2
a and *b* = are the panel dimensions in mm, *see* figures above
t_p = thickness of plating, in mm
φ = stress distribution factor for linearly varying compressive stress across plate width
= $0{,}47\ \mu^2 - 1{,}4\ \mu + 1{,}93$ for $\mu \geq 0$
= 1 for constant stress
μ = $\dfrac{\sigma_{d1}}{\sigma_{d2}}$ where σ_{d1} and σ_{d2} are the smaller and larger average compressive stresses respectively
E = Young's Modulus of elasticity of material, in N/mm^2
C = stiffener influence factor for panels with stiffeners perpendicular to compressive stress
= 1,3 when plating stiffened by floors or deep girders
= 1,21 when stiffeners are built up profiles or rolled angles
= 1,10 when stiffeners are bulb flats
= 1,05 when stiffeners are flat bars
σ_d and τ_d are the design compressive and design shear stresses in the direction illustrated in the figures. With linearly varying stress across the plate panel, σ_d is to be taken as σ_{d2}

Table 7.4.2 Plate panel buckling requirements

	Stress field	Buckling interaction formula	
(a)	uni-axial compressive loads	$\dfrac{\sigma_d}{\sigma_c} \leq \dfrac{1}{\lambda_\sigma}$	
(b)	shear loads	$\dfrac{\tau_d}{\tau_c} \leq \dfrac{1}{\lambda_\tau}$	

(c)	bi-axial compressive loads	for $A_R = 1{,}0$ $\frac{\sigma_{dx}}{\sigma_{cx}} + \frac{\sigma_{dy}}{\sigma_{cy}} \le 1{,}0$ for other aspect ratios, ie. $A_R \ne 1{,}0$ $\frac{\sigma_{dx}}{\sigma_{cx}} + \frac{\sigma_{dy}}{\sigma_{cy}} \le G$ when G is taken from *Figure 7.4.2 Secondary stiffening perpendicular to direction of compression*	
(d)	uni-axial compressive loads plus shear load	for $A_R > 1$ $\left(\frac{\sigma_d}{\sigma_c}\right) + \left(\frac{\tau_d}{\tau_c}\right)^2 \le 1$ for $A_R \le 1$ $\left(\frac{1 + 0,6A_R}{1,6}\right)\left(\frac{\sigma_d}{\sigma_c}\right) + \left(\frac{\tau_d}{\tau_c}\right)^2 \le 1$	
(e)	bi-axial compressive loads plus shear loads	$\frac{0,625\left(1 + \frac{0,6}{A_R}\right)\left(\frac{\sigma_{dy}}{\sigma_{cy}}\right)}{(1 - 0,625)\left(\frac{\sigma_{dx}}{\sigma_{cx}}\right)} + \frac{\left(\frac{\tau_d}{\tau_c}\right)^2}{1 - \left(\frac{\sigma_{dx}}{\sigma_{cx}}\right)}$ ≤ 1	
Symbols			

σ_d = design compressive stress, *see Pt 6, Ch 7, 4.1 General 4.1.3*

σ_c = critical compressive buckling stress, in N/mm^2, for uniaxial compressive load acting independently, *see Pt 6, Ch 7, 4.3 Plate panel buckling requirements 4.3.5*

σ_{dx} = design compressive stress in x direction

σ_{dy} = design compressive stress in the y direction

σ_{cx} = critical compressive buckling stress in x direction, *see Pt 6, Ch 7, 4.3 Plate panel buckling requirements 4.3.5*

σ_{cy} = critical compressive buckling stress in y direction, *see Pt 6, Ch 7, 4.3 Plate panel buckling requirements 4.3.5*

λ_σ = buckling factor of safety for compressive stresses, *see Pt 6, Ch 7, 4.3 Plate panel buckling requirements 4.3.4*

λ_τ = buckling factor of safety for shear stresses, *see Pt 6, Ch 7, 4.3 Plate panel buckling requirements 4.3.4*

τ_d = design shear stress, in N/mm^2

τ_c = critical shear buckling stress, in N/mm^2, acting independently, *see Pt 6, Ch 7, 4.3 Plate panel buckling requirements 4.3.5*

4.4.3 For welded plate panels with plating thicknesses below 8 mm the critical compressive buckling stress is to be reduced to account for the presence of residual welding stresses. The critical buckling stress is to be taken as the minimum of:

$$\sigma_{cr} = \sigma_e - \sigma_r$$

or

σ_c = as derived using *Pt 6, Ch 7, 4.4 Derivation of the buckling stress for plate panels 4.4.1*

where

σ_r = reduction in compressive buckling stress due to residual welding stresses

$$= \frac{2\beta_{RS}\sigma_o}{b/t_p}$$

β_{RS} = residual stress coefficient dependent on type of weld (average value of β_{RS} to be taken as 3) b, t_p and σ_o are defined in *Pt 6, Ch 7, 4.2 Symbols 4.2.1*

4.4.4 In general the effect of lateral loading on plate panels (for example hydrostatic pressure on bottom shell plating) may be neglected and the critical buckling stresses calculated considering the in-plane stresses only.

4.4.5 Unless indicated otherwise, the effect of initial deflection on the buckling strength of plate panels may be ignored.

4.5 Additional requirements for plate panels which buckle elastically

4.5.1 Elastic buckling of plate panels between stiffeners occurs when both the following conditions are satisfied:

(a) The design compressive stress, σ_d, is greater than the elastic buckling stress of the plating, σ_e,

$$\sigma_d > \sigma_e$$

(b) The elastic buckling stress is less than half the yield stress

$$\sigma_e \leq \frac{\sigma_o}{2}$$

4.5.2 Elastic buckling of local plating between stiffeners, including girders or floors etc, may be allowed if all of the following conditions are satisfied:

(a) The critical buckling stress of the stiffeners in all buckling modes is greater than the axial stress in the stiffeners after redistribution of the load from the elastically buckled plating into the stiffeners, hence

$$\frac{\sigma_{de}}{\sigma_{c(i)}} \leq \frac{1}{\lambda_\sigma}$$

(b) Maximum predicted loadings are used in the calculations.

(c) Functional requirements will allow a degree of plating deformation.

where

σ_{de} = is the stiffener axial stress given in *Pt 6, Ch 7, 4.5 Additional requirements for plate panels which buckle elastically 4.5.5*

$\sigma_{C(i)}$ = is given by *Table 7.4.3 Buckling stress of secondary stiffeners*

where

i = a, t, w or f depending on the mode of buckling.

λ_σ = is the buckling factor of safety

= 1,25

Table 7.4.3 Buckling stress of secondary stiffeners

Mode	Elastic buckling stress, N/mm^2	Critical buckling stress, N/mm^2 *see* Note 1
(a) Overall buckling (perpendicular to plane of plating without rotation of cross-section)	$\sigma_{e(a)} = C_f 0{,}001E \frac{I_a}{A_{te} l_e^2}$	$\sigma_{C(a)}$
(b) Torsional buckling	$\sigma_{e(t)} = \frac{0{,}001 E I_w}{I_p l_e^2}\left(m^2 + \frac{K}{m^2}\right) + 0{,}385E\frac{I_t}{I_p}$	$\sigma_{C(t)}$
(c) Web buckling (excluding flat bar stiffeners)	$\sigma_{e(w)} = 3{,}8E\left(\frac{t_w}{d_w}\right)^2$	$\sigma_{C(w)}$
(d) Flange buckling	$\sigma_{e(f)} = 0{,}39E\left(\frac{t_f}{b_f}\right)^2$	$\sigma_{C(f)}$

Symbols

d_w = web depth, in mm, (excluding flange thickness for rolled sections), *see Figure 7.4.4 Dimensions of longitudinals*

t_w = web thickness, in mm

b_f = flange width, in mm (including web thickness)

t_f = flange thickness, in mm. For bulb plates, the mean thickness of the bulb may be used, *see Figure 7.4.4 Dimensions of longitudinals*

l_e = effective span length of stiffener, in metres

C_f = end constraint factor

= 1 where both ends are pinned

= 2 where one end pinned and the other end fixed

= 4 where both ends are fixed

E = Young's Modulus of elasticity of the material, in N/mm^2

I_a = moment of inertia, in cm^4, of longitudinal, including attached plating of effective width b_{eb}, *see* Note

t_p and σ_o are given in *Pt 6, Ch 7, 4.2 Symbols 4.2.1*

A_{te} and b_{eb} are given in *Pt 6, Ch 7, 4.2 Symbols 4.2.1*

I_t = St.Venant's moment of inertia, in cm^4, of longitudinal (without attached plating)

= $\dfrac{d_w t_w^3}{3} 10^{-4}$ for flat bars

= $\dfrac{1}{3}\left[d_w t_w^3 + b_f t_f^3\left(1 - \dfrac{0,63 t_f}{b_f}\right)\right] 10^{-4}$ for built up profiles, rolled angles and bulb plates

I_p = polar moment of inertia, in cm^4, of profile about connection of stiffener to plating

= $\dfrac{d_w^3 t_w}{3} 10^{-4}$ for flat bars

= $\left(\dfrac{d_w^3 t_w}{3} + d_w^2 b_f t_f\right) 10^{-4}$ for built up profiles, rolled angles and bulb plates

I_w = sectorial moment of inertia, in cm^6, of profile and connection of stiffener to plating

= $\dfrac{d_w^3 t_w^3}{36} 10^{-6}$ for flat bars

= $\dfrac{t_f b_f^3 d_w^2}{12} 10^{-6}$ for 'Tee' profiles

= $\dfrac{b_f^3 d_w^3}{12\left(b_f + d_w\right)^2}\left(t_f\left(b_f^2 + 2b_f d_w + 4d_w^2\right) + 3t_w b_f d_w\right) 10^{-6}$ for '*L*' profiles, rolled angles and bulb plates

C = spring stiffness exerted by supporting plate panel

= $\dfrac{k_p E t_p^3}{3b\left(1 + \dfrac{1,33 k_p d_w t_p^3}{b t_w^3}\right)}$

k_p = 1 – η_p, and is not to be taken as less than zero. For built up profiles, rolled angles and bulb plates, k_p need not be taken less than 0,1

η_p = $\dfrac{\sigma_d}{\sigma_{ep}}$

σ_{ep} = elastic critical buckling stress, in N/mm^2, of the supporting plate derived from *Table 7.4.1 Buckling stress of plate panels*

m is determined as follows; e.g. m = 2 for K = 25

K	0 to 4	4 to 36	36 to 144	144 to 400	400 to 900	900 to 1764	$(m-1)^2 m^2$ to $m^2(m+1)^2$
m	1	2	3	4	5	6	m

$$K = \frac{1,03CS^4}{EI_w}10^4$$

σ_d is the design stress, in N/mm^2
all other symbols are as defined in *Pt 6, Ch 7, 4.2 Symbols 4.2.1*.

Note 1. The critical buckling stresses are to be derived from the elastic buckling stresses as follows:

$$\sigma_c = \sigma_e \text{ when } \sigma_e < \frac{\sigma_o}{2}$$

$$= \sigma_o\left(1 - \frac{\sigma_o}{4\sigma_e}\right) \text{ when } \sigma_e \geq \frac{\sigma_o}{2}$$

Note 2. For stiffeners attached to plating which buckles elastically, *see Pt 6, Ch 7, 4.5 Additional requirements for plate panels which buckle elastically*, the effective width of plating is to be taken as b_{eu}.

4.5.3 The effective breadth of attached plating for stiffeners, girder or beams that is to be used for the determination of the critical buckling stress of the stiffeners attached to plating which buckles elastically is to be taken as follows:

$$b_{eu} = \frac{b\sigma_u}{\sigma_o} \text{ mm}$$

where

σ_u = ultimate buckling strength of plating as given in *Pt 6, Ch 7, 4.5 Additional requirements for plate panels which buckle elastically 4.5.4*

b_{eu} = effective panel breadth perpendicular to direction of compressive stress being considered

b is given in *Pt 6, Ch 7, 4.2 Symbols 4.2.1*.

4.5.4 The ultimate buckling strength of plating, σ_υ, which buckles elastically, may be determined as follows:

(a) shortest edge loaded, i.e. $A_R \geq 1$:

$$\sigma_u = \sigma_o\left(\frac{1,9}{W} - \frac{0,8}{W^2}\right) \text{ N/mm}^2$$

(a) longest edge loaded, i.e. $A_R < 1$:

$$\sigma_u = \frac{1,77\sigma_o A_R^{0,78}}{W} \text{ N/mm}^2$$

where

$$\Omega = \frac{s}{t_p}\sqrt{\frac{\sigma_o}{E}}$$

A_R and s are defined in *Pt 6, Ch 7, 4.2 Symbols 4.2.1*.

t_p, E and σ_o are defined in *Pt 6, Ch 7, 4.2 Symbols 4.2.1*.

4.5.5 The axial stress in stiffeners attached to plating which is likely to buckle elastically is to be derived as follows:

$$\sigma_{de} = \sigma_d \frac{A_t}{A_{tb}}$$

where

σ_d is the axial stress in the stiffener when the plating can be considered fully effective

$$A_t = A_s + \frac{bt}{100} \text{ cm}^2$$

$$A_{tb} = A_s + \frac{b_{eu}t}{100} \text{ cm}^2$$

where

b and b_{eu} are given in *Pt 6, Ch 7, 4.5 Additional requirements for plate panels which buckle elastically 4.5.3*

t is the plating thickness, in mm

A_s is the stiffener area in cm^2

4.6 Shear buckling of stiffened panels

4.6.1 The shear buckling capability of longitudinally stiffened panels between primary members is to satisfy the following condition:

$$= \frac{\tau_d}{\tau_c} \leq \frac{1}{\lambda_\tau}$$

where

τ_c is derived from *Pt 6, Ch 7, 4.6 Shear buckling of stiffened panels 4.6.3*

τ_d is the design shear stress

λ_τ is given in *Table 7.4.4 Buckling factor of safety*.

4.6.2 The elastic shear buckling stress of longitudinally stiffened panels between primary members may be taken as:

$$\tau_e = K_s E \left(\frac{t}{s}\right)^2 \text{ for } A_R \geq 1$$

where

$$K_s = 4{,}5\left(\left(\frac{s}{1000l}\right)^2 + \frac{1}{N^2} + \left(\frac{N^2-1}{N^2}\right)\left(\frac{\omega}{1+\omega}\right)^r\right)$$

N = number of subpanels

$$= \frac{1000S_p}{s}$$

$$\omega = \frac{10I_{se}}{lt^3}$$

I_{se} = moment of inertia of a section, in cm^4, consisting of the longitudinal stiffener and a plate flange of effective width $s/2$

$$r = 1 - 0{,}75\left(\frac{s}{1000l}\right)$$

s, l, E and S_p are as defined in *Pt 6, Ch 7, 4.2 Symbols 4.2.1*, *see also Figure 7.4.1 Shear buckling of stiffened panels*.

4.6.3 The critical shear buckling stress, τ_χ, may be determined from τ_ε, *see* Note 2 in *Table 7.4.1 Buckling stress of plate panels*.

Table 7.4.4 Buckling factor of safety

Structural item	Buckling factor of safety (2) Compressive stresses, $\lambda\sigma$	Buckling factor of safety (3) Shear stresses, $\lambda\tau$
Bottom shell plating	1,0	–
Inner bottom plating	1,0	–
Deck plating	1,0	–
Side shell plating	1,0	1,1
Longitudinal bulkhead plating	1,0	1,1
Double bottom girders	1,0	1,1
Longitudinal girders	1,0	1,1
Superstructures/deckhouses (partially longitudinally effective)	1,0	–
Longitudinal secondary stiffeners	1,1(1)	–
Girder and floor web plating subject to local loads	1,1	1,2

Note 1. The buckling factor of safety for stiffeners attached to plating which is allowed to buckle in the elastic mode due to the applied loads is to be taken as 1,25, *see also Pt 6, Ch 7, 4.5 Additional requirements for plate panels which buckle elastically*.

Note 2 Buckling factor of safety to be applied to the compressive stress due to global longitudinal stresses.

Note 3 Buckling factor of safety to be applied to the shear stress.

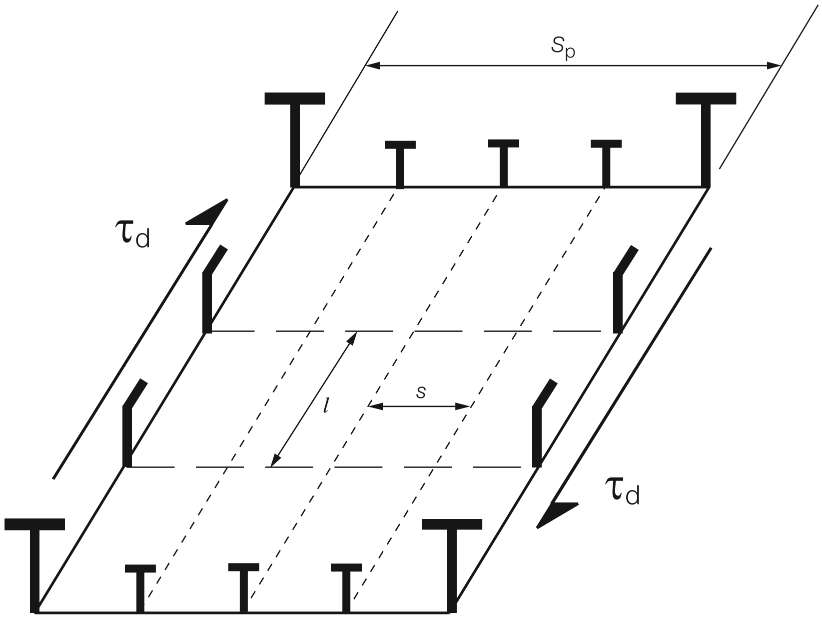


Figure 7.4.1 Shear buckling of stiffened panels

4.7 Secondary stiffening in direction of compression

4.7.1 The buckling performance of stiffeners will be considered satisfactory if the following conditions are satisfied:

$$\frac{\sigma_d}{\sigma_{c(a)}} \leq \frac{1}{\lambda_\sigma} \qquad \frac{\sigma_d}{\sigma_{c(t)}} \leq \frac{1}{\lambda_\sigma}$$

$$\frac{\sigma_d}{\sigma_{c(w)}} \leq \frac{1}{\lambda_\sigma} \qquad \frac{\sigma_d}{\sigma_{c(f)}} \leq \frac{1}{\lambda_\sigma}$$

where

= $\sigma_{c(a)}$, $\sigma_{c(t)}$, $\sigma_{c(w)}$ and $\sigma_{c(f)}$ are the critical buckling stress of the stiffener for each mode of failure, *see Pt 6, Ch 7, 4.7 Secondary stiffening in direction of compression 4.7.2*

= σ_d is the design compressive stress, *see also Pt 6, Ch 7, 4.5 Additional requirements for plate panels which buckle elastically* and *Pt 6, Ch 7, 4.1 General 4.1.3*

= λ_σ is the buckling factor of safety given in *Table 7.4.4 Buckling factor of safety*. The value of λ_σ to be chosen depends on the buckling assessment of the attached plating, *see* Note 1, *Table 7.4.4 Buckling factor of safety*.

4.7.2 The critical buckling stresses for the overall, torsional, web and flange buckling modes of longitudinals and secondary stiffening members under axial compressive loads are to be determined in accordance with *Table 7.4.3 Buckling stress of secondary stiffeners*.

4.7.3 To prevent torsional buckling of secondary stiffeners from occurring before buckling of the plating, the critical torsional buckling stress, $\sigma_{c(t)}$, is to be greater than the critical buckling stress of the attached plating as detailed in *Pt 6, Ch 7, 4.4 Derivation of the buckling stress for plate panels 4.4.1*

4.7.4 The critical buckling stresses of the stiffener web, $\sigma_{c(w)}$, and flange, $\sigma_{c(f)}$, are to be greater than the critical torsional buckling stress, hence:

$\sigma_{c(w)} > \sigma_{c(t)}$

$\sigma_{c(f)} > \sigma_{c(t)}$

4.7.5 To ensure that overall buckling of the stiffened panel cannot occur before local buckling of the secondary stiffener, the critical overall buckling stress $\sigma_{c(a)}$, is to be greater than the critical torsional buckling stress, hence:

$\sigma_{c(a)} > \sigma_{c(t)}$

4.8 Secondary stiffening perpendicular to direction of compression

4.8.1 Where a stiffened panel of plating is subjected to a compressive load perpendicular to the direction of the stiffeners, *see Figure 7.4.2 Secondary stiffening perpendicular to direction of compression*, e.g. a transversely stiffened panel subject to longitudinal compressive load, the requirements of this Section are to be applied.

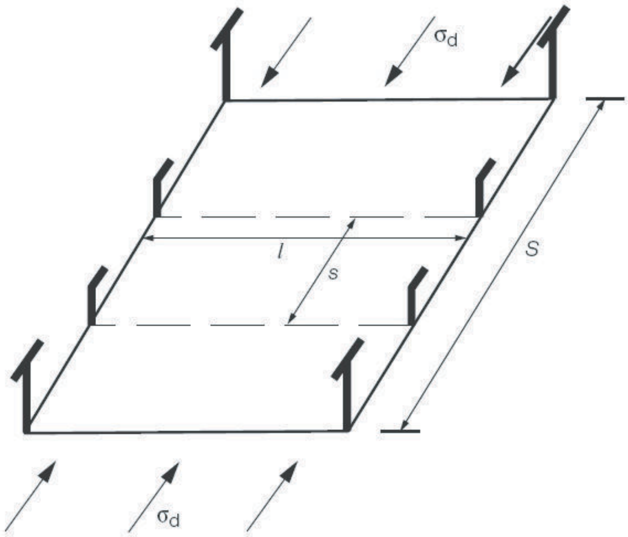


Figure 7.4.2 Secondary stiffening perpendicular to direction of compression

4.8.2 The minimum area moment of inertia of each stiffener including attached plating of width, *s*, to ensure that overall panel buckling does not precede plate buckling is to be taken as:

$$I_s = \frac{Ds\left(4N_L^{\,2} - 1\right)\left(\left(N_L^{\,2} - 1\right)^2 - 2\left(N_L^{\,2} + 1\right)\mathrm{k} + \mathrm{k}^2\right)}{2\left(5N_L^{\,2} + 1 - \mathrm{k}\right)\Pi^4 E} \text{ mm}^4$$

where

$D = \dfrac{Et_p^{\,3}}{12\left(1 - \upsilon^2\right)}$

$\mathrm{k} = A_R^{\,2}\Pi^2$

A_R = plate panel aspect ratio

$= \dfrac{s}{1000l}$

$\Pi = \dfrac{S}{l}$

N_L = number of plate panels

$N_L - 1$ = number of stiffeners

υ = 0,3

s, *l* and *S* are defined in *Pt 6, Ch 7, 4.2 Symbols 4.2.1* and shown in *Figure 7.4.2 Secondary stiffening perpendicular to direction of compression*.

t_p and *E* are defined in *Pt 6, Ch 7, 4.2 Symbols 4.2.1*.

4.9 Buckling of primary members

4.9.1 Where primary girders are subject to axial compressive loading, the buckling requirements for lateral, torsional, web and flange buckling modes detailed in *Pt 6, Ch 7, 4.7 Secondary stiffening in direction of compression* are to be satisfied.

4.9.2 To prevent global buckling from occurring before local panel buckling, transverse primary girders supporting axially loaded longitudinal stiffeners are to have a sectional moment of inertia, including attached plating, of not less than the following:

$$I_g = \frac{0,35 S_p{}^4 I_s}{l^3 s} \times 10^3 \text{cm}^4$$

S_p and *s* are as defined in *Pt 6, Ch 7, 4.2 Symbols 4.2.1*, *see also Figure 7.4.1 Shear buckling of stiffened panels*

I_g = sectional moment of inertia including attached plating

I_s = moment of inertia of secondary stiffeners, in cm^4, required to satisfy the overall elastic column buckling mode requirement specified in *Table 7.4.3 Buckling stress of secondary stiffeners*

$$= \frac{\sigma_{ep} A_{te} l_e^2}{0,001 E}$$

where

σ_{ep} = $1{,}2\sigma_d$ N/mm^2 for $\sigma_{e(a)} < \frac{\sigma_o}{2}$

$$= \frac{\sigma_o^2}{4(\sigma_o - 1,2\sigma_d)} \text{ for } \sigma_{e(a)} \geq \frac{\sigma_o}{2}$$

σ_d is design stress, in N/mm^2

σ_o and A_{te} are as defined in *Pt 6, Ch 7, 4.2 Symbols 4.2.1*

$\sigma_{e(a)}$ is the elastic column buckling stress, *see Pt 6, Ch 7, 4.7 Secondary stiffening in direction of compression 4.7.2*

E is defined in *Pt 6, Ch 7, 4.2 Symbols 4.2.1*.

l_e is defined in *Table 7.4.3 Buckling stress of secondary stiffeners*

4.10 Shear buckling of girder webs

4.10.1 Local panels in girder webs subject to in-plane shear loads are to satisfy the shear buckling requirements in *Table 7.4.2 Plate panel buckling requirements*, item (b).

4.10.2 The critical shear buckling stress, τ_c, is to be determined using the following formula for τ_ε and Note 1 in *Table 7.4.1 Buckling stress of plate panels*.

$$\tau_e = 3{,}62\left(1,335 + \left(\frac{d_w}{1000 l_p}\right)^2\right) E \left(\frac{t_w}{d_w}\right)^2 \text{ N/mm}^2$$

where

d_w = web height, in mm

t_w = web thickness, in mm

l_p = unsupported length of web, in metres

E is defined in *Pt 6, Ch 7, 4.2 Symbols 4.2.1*.

4.11 Pillars and pillar bulkheads

4.11.1 Pillars and pillar bulkheads are to comply with the requirements of *Pt 6, Ch 3, 10 Pillars and pillar bulkheads*.

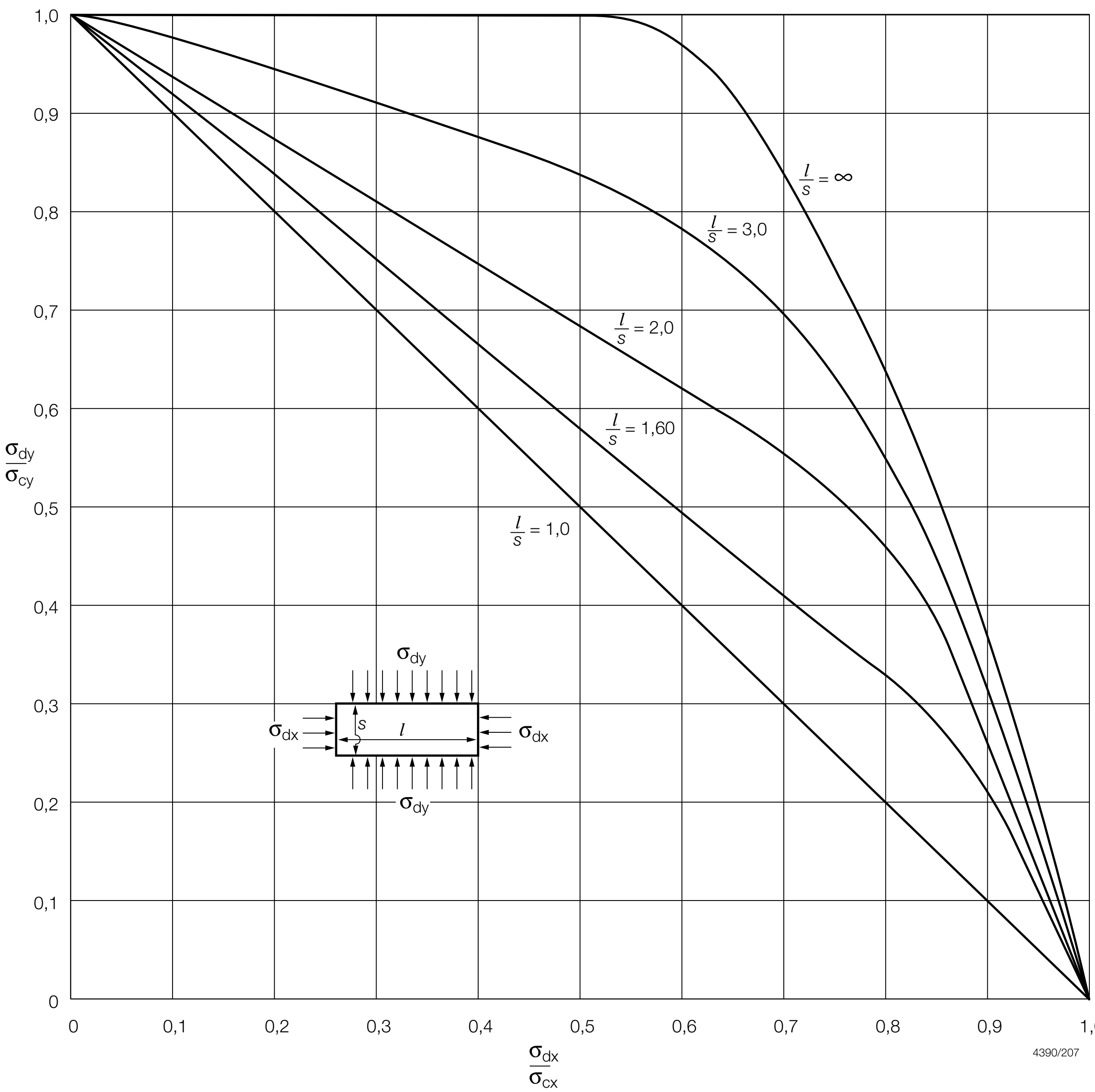


Figure 7.4.3 Interaction limiting stress curves of G for plate panels subject to bi-axial compression, *see Table 7.4.2 Plate panel buckling requirements*

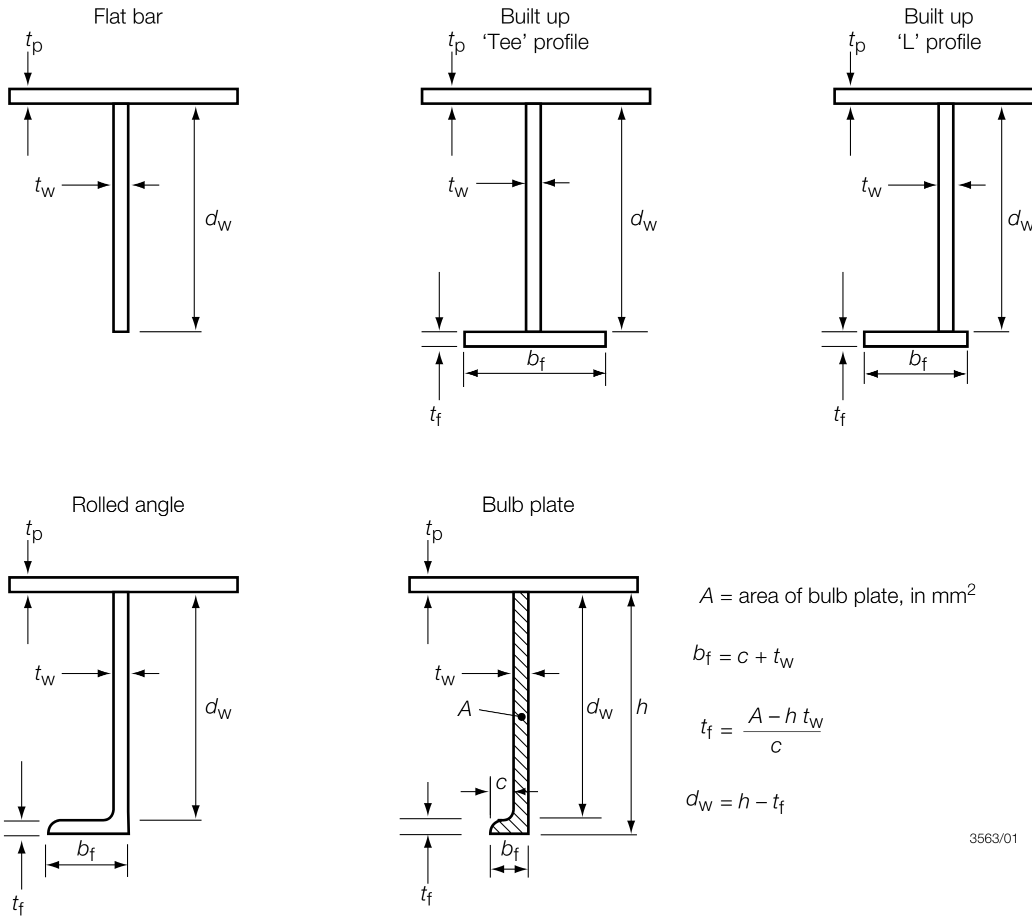


Figure 7.4.4 Dimensions of longitudinals

■ *Section 5* Vibration control

5.1 General

5.1.1 Natural frequencies are to be investigated for local unstiffened and stiffened panels expected to be exposed to excessive structural vibrations being induced from machinery, propulsion unit or other potential excitation sources.

5.1.2 Where the structural configurations are such that basic structural elements may be modelled individually the natural frequencies may be derived in accordance with *Pt 6, Ch 7, 5.3 Natural frequency of plate*, *Pt 6, Ch 7, 5.4 Natural frequency of plate stiffener* and *Pt 6, Ch 7, 5.5 Effect of submergence*, as appropriate. Under other circumstances finite element analysis is to be employed to evaluate the vibration characteristics of the structure considered.

5.2 Frequency band

5.2.1 The natural frequency of panels is generally not to lie within a band of ±20 per cent of a significant excitation frequency.

5.3 Natural frequency of plate

5.3.1 The natural frequency of a clamped plate in air is given by the following:

$$f_{air} = 5,544\frac{t_p}{ab}\sqrt{\left(\frac{a}{b}\right)^2 + \left(\frac{b}{a}\right)^2 + 0,6045}\ H_Z$$

where

a = panel length, in metres

b = panel breadth, in metres

t_p = panel thickness, in mm

5.4 Natural frequency of plate stiffener

5.4.1 The natural frequency of a plate stiffener in air is given by the following:

$$f_{air,\,i} = \frac{K_i}{2\,\pi\,L_b^2}\sqrt{\frac{EI}{m\left(1 + \frac{\pi^2 EI}{L_b^2 GA}\right)}}\ H_Z$$

where

$E\,I$ = flexural rigidity of plate stiffener combination, in Nm^2

GA = shear rigidity of plate stiffener combination, in N

L_b = beam length, in metres

m = mass per unit length of the stiffener and associated plating, in kg/m

K_i = constant where i refers to the mode of vibration as given in *Table 7.5.1 Vibration mode constant K_i*

Table 7.5.1 Vibration mode constant K_i

Mode	1	2	3	4	5
K_i	22,40	61,70	121,0	200,0	299,0

5.5 Effect of submergence

5.5.1 To obtain the frequency, f_{water}, of a plate with one side exposed to air and the other side exposed to a liquid, the frequency calculated in air, f_{air}, may be modified by the following formula:

$$f_{water} = \psi\, f_{air}$$

where

$$\psi = \sqrt{\frac{\kappa_p}{\kappa_p + \frac{\rho_l}{\rho_p}}}$$

ρ_l = density of the liquid, in kg/m^3

ρ_p = density of the plate, in kg/m^3

$\kappa_p = \frac{\pi\, t_p}{1000ab}\sqrt{a^2 + b^2}$

where a , b and t_p are as defined in *Pt 6, Ch 7, 5.3 Natural frequency of plate 5.3.1*.

Contents

Section

■ *Section 1* Application

1.1 General

1.1.1 The Rules apply to mono and multi-hull craft of normal form, proportions and speed. Although the Rules are, in general, for aluminium craft of all welded construction, other materials for use in hull construction will be specially considered on the basis of the Rules.

1.2 Interpretation

1.2.1 The interpretation of the Rules is the sole responsibility and at the sole discretion of Lloyd's Register (hereinafter referred to as 'LR'). Where there is any doubt, regarding the interpretation of the Rules it is the Builder's and/or designer's responsibility to obtain clarification from LR prior to submission of plans and data for appraisal.

1.2.2 Where applicable, the Rules take into account unified requirements and interpretations established by the International Association of Classification Societies (IACS).

1.2.3 Attention is drawn to the fact that Codes of Practice issued by IMO contain requirements which are outside classification as defined in the Rules.

1.3 Equivalents

1.3.1 Alternative scantlings and arrangements may be accepted as equivalent to the Rule requirements. Details of such proposals are to be submitted for consideration in accordance with *Pt 3, Ch 1, 3 Equivalents*.

1.3.2 Where the designer intends to submit an equivalent arrangement, it is the responsibility of the designer to ensure at an early stage that the proposed method and calculations are acceptable to LR. The case for the equivalent arrangement is to be supported by the following:

- goal of the requirement;
- reference(s) to published work supporting the proposed method; and
- acceptance criteria.

1.4 Symbols and definitions

1.4.1 The symbols and definitions for use throughout this Part are as defined within the appropriate Chapters and Sections.

■ *Section 2* General requirements

2.1 General

2.1.1 Limitations with regard to the application of these Rules are indicated in the various Chapters for differing craft types.

2.2 Aesthetics

2.2.1 LR is not concerned with the general arrangement, layout and appearance of the craft; the responsibility for such matters remains with the Builders and/or designers to ensure that the agreed specification is complied with. LR is however

concerned with the quality of workmanship, in this respect the acceptance criteria as required by the Rules are to be complied with.

2.3 Constructional configuration

2.3.1 The Rules provide for the basic structural configurations for both single and multi-deck mono and multi-hull craft with multi-deck or single deck hulls which include a double bottom, or a single bottom arrangement. The structural configuration may also include a single or multiple arrangement of cargo hatch openings and side tanks.

2.3.2 The Rules provide for longitudinal and transverse framing systems.

2.3.3 Novel or other types of framing systems will be considered on the basis of the Rules.

2.4 Plans to be submitted

2.4.1 Plans covering the following items are to be submitted:

- Midship sections showing longitudinal and transverse material.
- Profile and decks.
- Shell expansion.
- Oiltight and watertight bulkheads.
- Propeller brackets.
- Double bottom construction.
- Pillars and girders.
- Aft end construction.
- Engine room construction.
- Engine and thrust seatings.
- Fore end construction.
- Hatch cover construction.
- Deckhouses and superstructures.
- Sternframe.
- Rudder, stock and tiller.
- Equipment.
- Loading Manuals, preliminary and final (where applicable).
- Scheme of corrosion control (where applicable).
- Ice strengthening.
- Welding schedule.
- Hull penetration plans.
- Support structure for masts, derrick posts or cranes.
- Bilge keels showing material grades, welded connections and detail design.
- Any special arrangements (e.g. anchor deployment systems, submarine anchor pockets).

2.4.2 The following supporting documents are to be submitted:

- General arrangement.
- Capacity plan.
- Modes of operation for which the craft is designed (speeds corresponding to displacement and non-displacement mode as applicable).
- Lines plan or equivalent.
- Dry-docking plan.
- Towing and mooring arrangements.
- Sail/rigging plan, indicating loadings (as applicable to sailing craft).

2.4.3 The following supporting calculations are to be submitted:

- Equipment Number.
- Hull girder still water and dynamic bending moments and shear forces as applicable.
- Midship section modulus.

- Structural items in the aft end, midship and fore end regions of the craft.
- Preliminary freeboard calculation.

2.5 Novel features

2.5.1 Where the proposed construction of any part of the hull or machinery is of novel design, or involves the use of unusual material, or where experience, in the opinion of LR, has not sufficiently justified the principle or mode of application involved, special tests or examinations before and during service may be required. In such cases a suitable notation may be entered in the *Register Book*.

2.6 Enhanced scantlings

2.6.1 Where the Owner decides to increase the scantling of the bottom shell, side shell and deck plating of a newbuilding, then the craft will be eligible to be assigned the description note **ES**, *see Pt 1, Ch 2, 3.12 Descriptive notes*. For example, the descriptive note **ES+1** would indicate that an extra 1 mm of aluminium has been fitted to bottom shell, side shell and deck plating.

2.7 Direct calculations

2.7.1 Direct calculations may be specifically required by the Rules and may be required for craft having novel design features or in support of alternative arrangements and scantlings. LR may, when requested, undertake calculations on behalf of designers and make recommendations with regard to suitability of any required model tests.

2.7.2 Where direct calculations are proposed then the requirements of *Pt 3, Ch 1, 2 Direct calculations* of the Rules are, in general, to be complied with.

2.8 Exceptions

2.8.1 Craft of unusual form, proportions or speed, intended for the carriage of special cargoes, or for special or restricted service, not covered specifically by the Rules, will receive individual consideration based on the general requirements of the Rules.

2.9 Advisory services

2.9.1 The Rules do not cover certain technical characteristics, such as stability except as mentioned in *Pt 1, Ch 2, 1.1 General 1.1.11* and *Pt 1, Ch 2, 1.1 General 1.1.13*, trim, vibration (other than local stiffened flat panels, *see Pt 7, Ch 7, 5 Vibration control*), docking arrangements, etc. The Committee cannot assume responsibility for these matters but is willing to advise upon them on request.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull and multi-hull craft of aluminium construction as defined in *Ch 1, 1 Background*.

1.2 General

1.2.1 This Chapter contains the general Rule requirements for the construction of aluminium craft using the metal inert gas (MIG) and tungsten inert gas (TIG) welding processes. Where alternative methods of construction are proposed, details are to be submitted for consideration by Lloyd's Register (hereinafter referred to as 'LR').

1.3 Symbols and definitions

1.3.1 The symbols and definitions used in this Chapter are defined in the appropriate Section.

1.4 Builder's facilities

1.4.1 The buildings used for production and storage are to be of suitable construction and equipped to provide the required environment, and also to comply with any local or National Authority requirements.

1.4.2 The Surveyor is to be allowed unrestricted access during working hours to such parts of the Builder's establishment as may be necessary to ensure that the requirements of the Rules are being complied with.

1.5 Works inspection

1.5.1 Prior to the commencement of construction, the facilities are to be inspected to the satisfaction of the attending Surveyor. This will include the minimum quality control arrangements outlined in *Pt 7, Ch 2, 1.6 Quality control*.

1.5.2 The Surveyor is to be satisfied that the Builder has the organisation and capability to construct craft to the standards required by the Rules.

1.5.3 The Builder is to be advised of the result of the inspection and all deficiencies are to be rectified prior to the commencement of production.

1.5.4 Where structural components are to be assembled and welded by sub-contractors, the Surveyors are to inspect the sub-contractor's works to ensure that compliance with the requirements of this Chapter can be achieved.

1.6 Quality control

1.6.1 For compliance with *Pt 7, Ch 2, 1.5 Works inspection 1.5.2*, LR's methods of survey and inspection for hull construction and machinery installation are to include procedures involving the shipyard management, organisation and quality systems.

1.6.2 The extent and complexity of the quality systems, will vary considerably depending on the size and type of craft and production output. LR will consider certification of the Builder in accordance with the requirements of one of the following systems:

(a) Quality Assurance System in accordance with an International or National Standard (i.e. ISO 9000 and BS ENISO 9001) with assessment and certification carried out by a nationally accredited body.

(b) LR's locally accepted Quality Control System - The Builder is required to implement a documented Quality Control System which controls the following activities:
   (i) Receipt storage and issue of materials, equipment, etc.
   (ii) Fabrication environment.
   (iii) Weld procedures and welder performance
   (iv) Production fabrication.
   (v) Inspection of production processes.
   (vi) Installation of machinery and essential systems.
   (vii) Fitting-out.
   (viii) Tests and trials.
   (ix) Drawings and document control.
   (x) Records.

1.6.3 LR's involvement is only in that part of the system which controls the standards required to meet the classification requirements.

1.6.4 The `documented' quality control system will in general require the Builder to have written procedures that describe clearly and unambiguously how each of the activities specified in *Pt 7, Ch 2, 1.6 Quality control 1.6.2.(b)* is carried out, when it is carried out and by whom. These procedures will form part of the system manual which is also to contain a statement of management policy, organisation chart and statements of responsibilities. The manual is to be controlled in respect to the formal issue and revision.

1.6.5 Further details of LR's requirements are available on request from the local LR office.

1.7 Building environment

1.7.1 The craft is to be suitably protected during the building period from adverse weather and climatic conditions.

1.8 Storage areas

1.8.1 All materials are to be stored safely and in accordance with the manufacturer's requirements. Storage arrangements are to be such as to prevent deterioration through contact with heat, sunlight, damp, cold and poor handling.

1.8.2 Aluminium is to be stored in dry places, clear of the ground. Contact with other metals and with materials such as cement and damp timber is to be avoided. Aluminium sheet and plate are to be stacked, in general, on end in racks to avoid distortion.

1.8.3 All storage spaces provided by the Builder for welding consumables are to be suitable for maintaining them in good condition and are to be in accordance with the manufacturer's recommendations.

1.8.4 All materials are to be fully identifiable in the storage areas, and identification is to be maintained during issue to production.

1.8.5 Material suspected of being non-conforming is to be segregated from acceptable materials.

1.9 Materials handling

1.9.1 The Builder is to maintain purchasing documents containing a clear description of the materials ordered for use in hull construction and the standards to which the material must conform, together with the identification and certification requirements.

1.9.2 The Builder is to be responsible for ensuring that all incoming plates, sections, castings, components, fabrications and consumables and other materials used in the hull construction are inspected or otherwise verified as conforming to purchase order requirements.

1.9.3 The Builder is to have procedures for the inspection, storage and maintenance of Owner supplied materials and equipment.

1.9.4 The Builder is to record on receipt the manufacturing date, or use-by date of critical materials. Any materials which have a shelf life are to be used in order of manufacturing date to ensure stock rotation.

1.9.5 The Builder is to establish and maintain a procedure to ensure that materials and consumables used in the hull construction process are identified (by colour-coding and/or marking as appropriate) from arrival in the yard through to fabrication in such a way as to enable the type and grade to be readily recognised.

1.9.6 Where materials are found to be defective they are to be rejected in accordance with the Builder's quality control procedure.

1.10 Faults

1.10.1 All identified faults are to be recorded under the requirements of the quality control systems. Faults are to be classified according to their severity and are to be monitored during periodical survey.

1.10.2 Production faults are to be discussed with the attending Surveyor and a rectification scheme agreed. Deviations from the approved plans are to be locally approved by the attending Surveyor and a copy forwarded to the plan approval office for record purpose.

1.11 Inspection

1.11.1 On acceptance of a `Request for Services' the attending Surveyor is to inform the Builder of the key stages of the production that are to be inspected and the extent of the inspection to be carried out.

1.11.2 It is the Builder's responsibility to carry out required inspections in accordance with the accepted quality control system.

1.11.3 It is the Surveyor's responsibility to monitor the Builder's quality control records and carry out inspections at key stages and during periodic visits.

1.11.4 Adequate facilities are to be provided to enable the Surveyor to carry out a satisfactory inspection and to facilitate subsequent in-service maintenance. These are to include the provision of access holes in restricted spaces and removable deckhead and shipside linings, cabin soles, etc.

1.11.5 During inspections all deviations are to be dealt with in accordance with *Pt 7, Ch 2, 1.6 Quality control 1.6.4*.

1.12 Acceptance criteria

1.12.1 Classification is dependent upon the work being carried out in accordance with the approved plans and the requirements of an accepted quality control system.

1.12.2 The work is to be carried out to the satisfaction of the attending Surveyor. This will include the verification of the quality control documentation and the remedial action associated with all defects and deficiencies recorded.

1.12.3 Proposed deviations from the approved plans are subject to LR approval and in the first instance are to be discussed with the attending Surveyor. Where applicable, an amended plan is to be submitted to the plan appraisal office. Such deviations will be recorded as endorsements to the certification unless specifically agreed otherwise with the plan appraisal office.

1.12.4 Where the above requirements are met the attending Surveyor will arrange for the relevant certification to be issued.

1.13 Repair

1.13.1 Minor repairs are to be agreed with the attending Surveyor and a rectification scheme agreed with the Builder. The Builder is to incorporate details of the agreed repair procedures in the quality control system in accordance with *Pt 7, Ch 2, 1.6 Quality control 1.6.4*.

1.13.2 Repairs which affect the structural integrity are to be discussed with the Builder and the Builder's proposed rectification scheme is to be submitted to the plan appraisal office for consideration.

■ *Section 2* Materials

2.1 General

2.1.1 The materials used in the construction of the craft are to be manufactured and tested in accordance with the appropriate requirements of *Ch 8 Aluminium Alloys*the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

2.1.2 As an alternative to *Pt 7, Ch 2, 2.1 General 2.1.1*, materials may be accepted for specific applications, provided they are manufactured and tested in accordance with the requirements of national or proprietary specifications which give reasonable

equivalence to the requirements of the *Rules for the Manufacture, Testing and Certification of Materials, July 2021*. Additional tests may be required to prove that the materials are suitable for the intended purpose in respect of mechanical properties, weldability and corrosion resistance.

2.1.3 All materials are to be manufactured at works which have been approved by LR for the type and, where appropriate, grade of aluminium which is being supplied and for the relevant aluminium production and processing route.

2.2 Aluminium alloy plates, bars and sections

2.2.1 Materials are, in general, to be limited to the supply conditions detailed in *Ch 8, 1.6 Heat treatment* of the Rules for Materials. Other supply conditions may be accepted but, as materials in a condition other than annealed are subject to a loss of mechanical strength in the vicinity of welded joints, the strength used in design calculations are to be as given in *Pt 7, Ch 2, 2.4 Mechanical properties for design*.

2.2.2 For applications where the material will be subject to high local stresses, it is recommended that the scantlings, when using higher strength materials, be determined on the basis of the mechanical properties of the material in the as-welded annealed condition.

2.3 Aluminium alloy castings

2.3.1 All structural castings are to be manufactured and tested in accordance with the appropriate requirements of *Ch 8, 3 Aluminium alloy castings*.

2.4 Mechanical properties for design

2.4.1 The minimum tensile strength properties of aluminium alloys approved for structural use are given in *Ch 13, 8.3 Fabrication and welding 8.3.2* of the Rules for Materials. Other alloys and conditions of temper may be accepted in accordance with *Pt 7, Ch 2, 2.1 General 2.1.3*.

2.4.2 In general, for welded structure, the maximum value for the strength of the material, σ_a, to be used in the scantling derivation is that of the aluminium alloy in the welded condition, where σ_a is defined as the 0,2 percent butt welded proof stress or 70 per cent of the ultimate strength of the material in the welded condition in N/mm^2, whichever is the lesser.

2.4.3 The tensile modulus of elasticity to be used in scantling calculations is 69 x 10^3 N/mm^2 for all aluminium alloy materials.

2.4.4 The type of material, specification to which it is manufactured (including grade and temper) and minimum guaranteed mechanical properties are to be indicated on the construction drawings.

2.5 Cathodic protection

2.5.1 The potential of the aluminium-magnesium (5000 Series) and the aluminium-magnesium-silicon (6000 Series) alloys is generally in the range -0,7 to -0,9 Volts with reference to a silver/silver chloride sea water reference electrode. A negative potential swing of at least 0,1 Volts from the corrosion potential is necessary to provide cathodic protection in sea water (i.e. -0,8 to -1,0 Volts). The limit of negative potential is, however, not to exceed -1,1 Volts with reference to a silver/silver chloride sea water reference electrode. Zinc or aluminium-zinc-indium or aluminium-zinc-tin anodes may be used for cathodic protection but aluminium anodes containing mercury are not acceptable.

2.5.2 Where a cathodic protection system is fitted, plans showing the proposed layout of anodes and hull penetrations are to be submitted in accordance with *Ch 15 Corrosion Prevention* of the Rules for Materials.

2.6 Paints and coatings

2.6.1 The hull, deck, deckhouse and superstructure and other structure which is exposed to the marine environment is to be protected against corrosion by a suitable protective coating, *see Ch 15 Corrosion Prevention* of the Rules for Materials. Internal structures need not in general be coated provided that they are built of aluminium alloy grades shown in *Ch 8 Aluminium Alloys* of the Rules for Materials.

2.6.2 Aluminium alloy is to be suitably cleaned, cleared of oxide and degreased before the application of any protective coating.

2.6.3 Paints containing lead, mercury or copper are not to be used in conjunction with aluminium alloys.

2.7 Galvanic action

2.7.1 Where bimetallic connections are made, involving dissimilar metals, measures are to be incorporated to preclude galvanic corrosion. In order to prevent galvanic corrosion, special attention is to be given to the penetrations of and connections to the hull, bulkheads and decks by piping and equipment where dissimilar materials are involved.

2.8 Bimetallic connections

2.8.1 The design is to ensure that the location of all bimetallic connections allows for regular inspection and maintenance of the joints and penetrations during service.

2.9 Deck coverings

2.9.1 Where plated decks are sheathed with wood, the sheathing is to be efficiently attached to the deck, caulked and sealed, to the satisfaction of the Surveyor in accordance with the approved drawings.

2.9.2 Deck coverings in the following positions are to be of a type which will not readily ignite where used on decks:

(a) Forming the crown of machinery or cargo spaces within accommodation spaces of cargo craft.
(b) Within accommodation spaces, control stations, stairways and corridors of passenger craft.

2.10 Corrosion margin

2.10.1 The scantlings determined from the formulae provided in the Rules assume that the materials used are selected, manufactured and protected in such a way that there is negligible loss in strength by corrosion.

2.10.2 Where aluminium alloy is not protected against corrosion, by painting or other approved means, the scantlings may require to be further considered.

2.11 Fracture control

2.11.1 Aluminium alloys in commercial use are in general not subject to unstable crack growth in an elastic stress field because fracture toughness is high. However, for alloys with higher strength and/or temper, special tests may be required to provide information on fracture toughness.

2.11.2 Construction procedures, materials and welding are to be in accordance with the requirements of this Chapter such that stress corrosion cracking is avoided.

2.11.3 High local stresses are to be avoided by the use of suitable design detail, *see also* LR's *Guidance Notes for Structural Details*.

■ *Section 3*
Procedures for welded construction

3.1 General

3.1.1 Except as otherwise indicated below, all welded construction is to be conducted in accordance with the requirements specified in *Ch 13 Requirements for Welded Construction* of the Rules for Materials.

3.1.2 Cast aluminium alloys are not in general to be welded directly to wrought high magnesium alloys unless the welding is carried out in accordance with an agreed procedure.

3.2 Information to be submitted

3.2.1 The plans and information submitted for approval are to clearly indicate details of the welded connections of the main structural members, including the type, disposition and size of welds.

3.3 Defined practices and welding sequence

3.3.1 The final boring out of propeller brackets and sterntubes and the fit-up and alignment of rudder bearings and jet units are to be carried out after the major part of the welding of the aft end of the craft is complete. The contacts between rudder stocks and propeller shafts with bearings are to be checked before the final mounting.

3.4 Structural arrangements and access

3.4.1 Ceilings, cabin sole, side and overhead linings are to be secured in such a manner as to be easily removed for the maintenance and inspection of the structure below.

3.4.2 Structural arrangements are to be such as will allow adequate ventilation and access for preheating, where required, and for the satisfactory completion of all welding operations. Welded joints are to be so arranged as to facilitate the use of downhand welding wherever possible.

3.5 Heat treatment

3.5.1 For aluminium-magnesium alloys, the preheating temperature is to be limited to 60ºC to avoid the risk of stress corrosion cracking.

3.5.2 With the 6000 series heat-treatable alloys, it is sometimes beneficial to apply a post-weld heat treatment in the form of artificial ageing. The procedure to be used depends on the alloy and, in order to quantify the benefits, tests are required using representative specimens which accurately simulate the true situation in terms of metal thickness, geometry, filler metal and welding parameters, as well as the post-weld treatment employed.

3.6 Inspection and non-destructive examination

3.6.1 Inspection of welded construction is to be conducted in accordance with the requirements specified in *Ch 13 Requirements for Welded Construction* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2021*, and the general NDE requirements as per *Ch 1, 5.1 General NDE requirements* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2021*.

3.6.2 Checkpoints for volumetric examination are to be selected so that a representative sample of welding is examined.

3.6.3 Typical locations for volumetric examination and number of checkpoints to be taken are shown in *Table 2.3.1 Non-destructive examination of welds*. A list of the proposed items to be examined is to be submitted for approval.

Table 2.3.1 Non-destructive examination of welds

Volumetric non-destructive examinations - Recommended extent of testing, *see Pt 7, Ch 2, 3.6 Inspection and non-destructive examination 3.6.3*		
Item	Location	Checkpoint, *see*Note 1
Intersections of butts and seams of fabrication and section welds	Throughout: • hull envelope • longitudinal and transverse bulkheads • inner bottom and hopper bottom	The summation of checkpoint lengths (see Note 2) examined at intersections is to be L, where L is the overall length of the ship in metres
Butt welds in plating	Throughout	1 m in 25 m, *see* Note 3
Seam welds in plating	Throughout	1 m in 100 m
Butts in longitudinals	Hull envelope within 0,4*L* amidships Hull envelope outside 0,4*L* amidships	1 in 10 welds 1 in 20 welds
Bilge keel butts	Throughout	1 m in 20 m
Structural items when made with full penetration welding as follows: • connection of stool and bulkhead to lower stool shelf plating • vertical corrugations to an inner bottom • hopper knuckles • sheerstrake to deck stringer • hatchways coaming to deck	Throughout	1 m in 20 m
Note 1. The length of each checkpoint is to be between 0,3 m and 0,5 m. Note 2. For checkpoints at intersections the measured dimension of length is to be in the direction of the butt weld. Note 3. Checkpoints in butt welds and seam welds are in addition to those at intersections. Note 4. Agreed locations are not to be indicated on the blocks prior to the welding taking place, nor is any special treatment to be given at these locations. Note 5. Particular attention is to be given to repair rates in longitudinal butts. Additional welds are to be tested in the event that defects, such as lack of fusion or incomplete penetrations, are repeatedly observed.		

3.7 Acceptance criteria

3.7.1 All finished welds are to be sound and free from cracks and substantially free from lack of fusion, incomplete penetration, porosity and tungsten inclusions. The surfaces of welds are to be reasonably smooth and substantially free from undercut and overlap. Care is to be taken to ensure that the specified dimensions of welds have been achieved and that both excessive reinforcement and underfill of welds are avoided.

3.7.2 The acceptance criteria are to be in accordance with *Ch 13, 8 Specific requirements for welded aluminium* of the Rules for Materials.

■ *Section 4*
Joints and connections

4.1 General

4.1.1 Requirements are given in this Chapter for welding connection details, aluminium/steel transition joints, aluminium/wood connection, riveting of light structure and chemical bonding.

4.1.2 Welded joints are to be detailed such that crevices or inaccessible pockets capable of retaining dirt or moisture are avoided. Where cavities are unavoidable, they are to be sealed by welding or protective compounds or made accessible for inspection and maintenance.

4.2 Weld symbols

4.2.1 Weld symbols, where used, are to conform to a recognised National or International Standard. Details of such Standards are to be indicated on the welding schedule, which is to be submitted for appraisal.

4.3 Welding schedule

4.3.1 A welding schedule containing not less than the following information is to be submitted:

(a) Weld throat thickness or leg lengths.
(b) Grades, tempers, and thicknesses of materials to be welded.
(c) Locations, types of joints and angles of abutting members.
(d) Reference to welding procedures to be used.
(e) Sequence of welding of assemblies and joining up of assemblies.

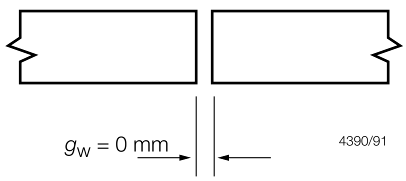
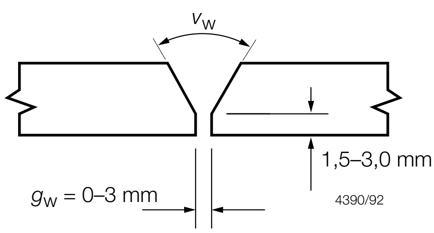
4.4 Butt welds

4.4.1 All structural butt joints are to be made by means of full penetration welds and, in general, the edges of plates to be joined by welding are to be bevelled on one or both sides of the plates. Full details of the proposed joint preparation are to be submitted for approval, *see also Pt 7, Ch 2, 4.19 Joint preparation*.

4.4.2 Where butt welds form a T-junction, the leg of the T is, where practicable, to be completed first including any back run. During the welding operation special attention is to be given to the completion of the weld at the junction, which is to be chipped back to remove crater cracks, etc. before the table is welded.

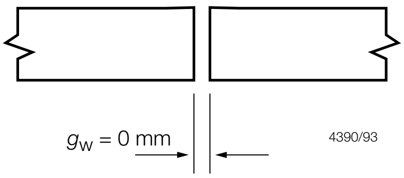
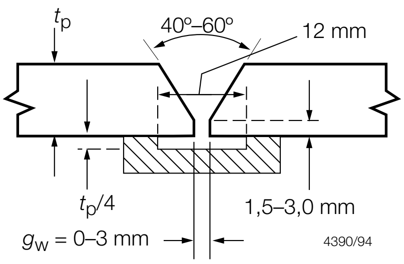
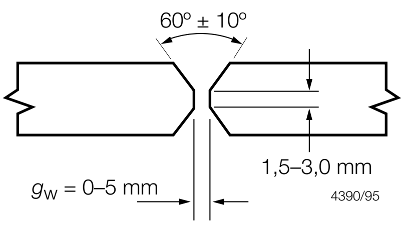
4.4.3 For guidance purposes, a number of typical joint preparations for TIG and MIG welding are shown in *Table 2.4.1 Typical joint preparations for TIG welding of aluminium alloys* and *Table 2.4.2 Typical joint preparations for semi-automatic MIG welding* respectively.

Table 2.4.1 Typical joint preparations for TIG welding of aluminium alloys

Thickness (mm)	Joint design	Welding position/ comments
2,5 – 3,0		Flat Horizontal Vertical Overhead
3,0 – 10,0		Flat and Vertical V = 60° Horizontal and Overhead V = 90° – 110°

Symbols and definitions
g_w = weld gap, in mm
V_w = weld preparation angle, in degrees

Table 2.4.2 Typical joint preparations for semi-automatic MIG welding

Thickness (mm)	Joint design	Welding position/ comments
5,0 – 6,5		Flat
7,0 – 15,0		Flat Horizontal Vertical Overhead One sided welding with temporary backing
12,0 – 25,0		All positions
Symbols and definitions		
t_p = plate thickness, in mm g_w = weld gap, in mm		

4.5 Fillet welds

4.5.1 The throat thickness of fillet welds is to be not less than:

$$\text{Throat thickness} = t_p \times \text{Weld factor} \times \left(\frac{d}{s}\right) \text{mm}$$

where

s = the length, in mm, of the fillet that is fully formed and weld clear of any end dressing, as illustrated in *Figure 2.4.1 Weld dimensions and types*

d = the distance between successive weld fillets, in mm

t_p = plate thickness, in mm, on which weld fillet size is based, *see Pt 7, Ch 2, 4.5 Fillet welds 4.5.5*.

For weld fillet dimensions, *see Figure 2.4.1 Weld dimensions and types*.

Weld factors are contained in *Table 2.4.3 Weld factors*.

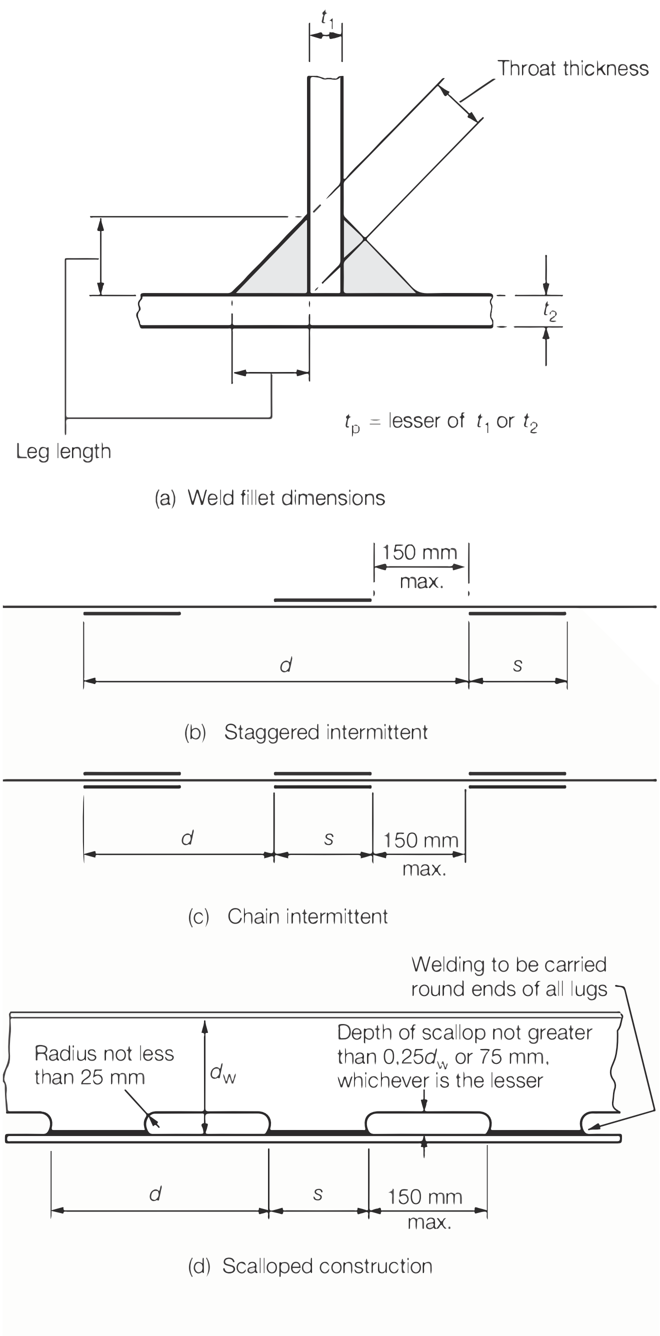


Figure 2.4.1 Weld dimensions and types

4.5.2 The length, in mm, of any weld fillet in any intermittent welding arrangement is to be at least $10t_p$ or 40 mm, whichever is the greater but need not exceed 75mm.

4.5.3 For ease of welding, it is recommended that the ratio of the web height to the flange breadth be greater than or equal to 1,5, *see Figure 2.4.2 Web height/flange breadth ratio*.

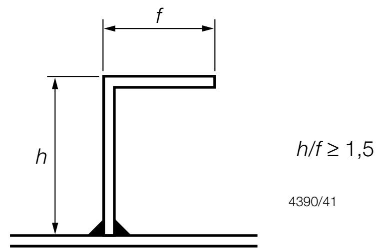


Figure 2.4.2 Web height/flange breadth ratio

Table 2.4.3 Weld factors

Item	Weld factor	Remarks
(1) General application:		except as required below
(a) Shell envelope boundary, including sea chests and hull penetrations	Full penetration	For hull penetrations, fitted with a flange or other support, equivalent arrangements may be considered.
(b) Watertight plate boundaries	0,34	
(c) Non-tight plate boundaries	0,13	
(d) Longitudinals, frames, beams,and other secondary members to shell, deck, or bulkhead plating	0,10	
	0,13	in tanks
	0,21	in way of end connections
(e) Panel stiffeners	0,10	
(f) Overlap welds generally	0,27	
(g) Longitudinals of the flat-bar type to plating		*see Pt 7, Ch 2, 4.8 Double continuous fillet welding 4.8.5*
(2) Bottom construction:		
(a) Non-tight centre girder		
• to keel	0,27	
• to inner bottom	0,21	no scallops
(b) Non-tight boundaries of :		
• floors, girders and	0,21	in way of 0,1 x span at ends
• brackets	0,27	in way of brackets at lower end of main frame
Watertight bottom girders	0,34	
Connection of girder to inner bottom in way of longitudinal bulkheads supported on inner bottom	0,44	
(c) Inner bottom longitudinals, or face flat to floors reverse frames	0,13	

	(d) Connection of floors to inner bottom where bulkhead supported on tank top. The supporting floors are to be continuously welded to the inner bottom	0,44	Weld size based on floor thickness Weld material compatible with floor material
(3)	Hull framing:		
	(a) Webs of web frames and stringers:		
	• to shell	0,16	
	• to face plate	0,13	
(4)	Decks and supporting structure:		
	(a) Weather deck plating to shell	0,44	
	Other decks to shell and bulkheads (except where forming tank boundaries)	0,21	generally continuous
	(b) Webs of cantilevers to deck and to shell in way of root bracket	0,44	
	(c) Webs of cantilevers to face plate	0,21	
	(d) Girder webs to deck clear of end brackets	0,10	
	(e) Girder webs to deck in way of end brackets	0,21	
	*(f)*Web of girder to face plate	0,10	
	(g) Pillars:		
	• fabricated	0,10	
	• end connections	0,34	
	• end connections (tubular)	full penetration	
	(h) Girder web connections and brackets in way of pillar heads and heels	0,21	continuous
(5)	Bulkheads and tank construction:		
	(a) Plane and corrugated watertight bulkhead boundary at bottom, bilge, inner bottom, deck and connection to shelf plate, where fitted	0,44	Weld size to be based on thickness of bulkhead Weld material to be compatible with bulkhead plating material
	(b) Secondary members where acting as pillars	0,13	
	(c) Non-watertight pillar bulkhead boundaries	0,13	
	(d) Perforated flats and wash bulkhead boundaries	0,10	
	(e) Deep tank horizontal boundaries at vertical corrugations	full penetration	
(6)	Structure in machinery space:		
	(a) Centre girder to keel and inner bottom	0,27	no scallops to inner bottom
	(b) Floors to centre girder in way of engine thrust bearers	0,27	
	(c) Floors and girders to shell and inner bottom	0,21	
	(d) Main engine foundation girders:		
	• to top plate	deep penetration to depend on design	edges to be prepared with maximum root $0,33t_p$ deep penetration, generally

	• to hull structure	deep penetration to depend on design	edges to be prepared with maximum root $0{,}33t_p$ deep penetration, generally
	(e) Floors to main engine foundation girders	0,27	
	(f) Brackets, etc. to main engine foundation girders	0,21	
	(g) Transverse and longitudinal framing to shell	0,13	
(7)	Superstructures and deckhouses:		
	(a) Connection of external bulkheads to deck	0,34	1st and 2nd tier erections
		0,21	elsewhere
	(b) Internal bulkheads	0,13	
(8)	Steering control systems:		
	(a) Rudder:		
	• Fabricated mainpiece and	0,44	
	• mainpiece to side plates and webs		
	(b) Slot welds inside plates		
	(c) Remaining construction		
	(d) Fixed and steering nozzles:		
	• Main structure	0,44	
	• Elsewhere	0,21	
	(e) Fabricated housing and structure of thruster units, stabilisers, etc.:		
	• Main structure	0,44	
	• Elsewhere	0,21	
(9)	Miscellaneous fittings and equipment:		
	(a) Rings for manhole type covers, to deck or bulkhead	0,34	
	(b) Frames of shell and weathertight bulkhead doors	0,34	
	(c) Stiffening of doors	0,21	
	(d) Ventilator, air pipes, etc. coamings to deck	0,34	Load Line Positions 1 and 2
		0,21	elsewhere
	(e) Ventilator, etc. fittings	0,21	
	(f) Scuppers and discharges, to deck	0,44	
	(g) Masts, crane pedestals, etc. to deck	0,44	full penetration welding may be required
	(h) Deck machinery seats to deck	0,21	generally
	(j) Mooring equipment seats	0,21	generally, but increased or full penetration may be required
	(k) Bulwark stays to deck	0,21	
	(l) Bulwark attachment to deck	0,34	

(m) Guard rails, stanchions, etc. to deck	0,34	
(n) Bilge keel ground bars to shell	0,34	continuous fillet weld, minimum throat thickness 4 mm
(o) Bilge keels to ground bars	0,21	light continuous or staggered intermittent fillet weld, minimum throat thickness 3 mm
(p) Fabricated anchors	full penetration	

4.5.4 The leg length of the weld is to be not less than $\sqrt{2}$ times the specified throat thickness.

4.5.5 The plate thickness t_p to be used in *Pt 7, Ch 2, 4.5 Fillet welds 4.5.1* is generally to be that of the thinner of the two parts being joined. Where the difference in thickness is considerable, the size of fillet will be specially considered.

4.6 Throat thickness limits

4.6.1 The throat thickness limits given in *Table 2.4.4 Throat thickness limits* are to be complied with.

4.6.2 Where the throat thickness calculated in *Pt 7, Ch 2, 4.5 Fillet welds 4.5.1* is less than the overriding minimum value, as required by *Table 2.4.4 Throat thickness limits*, the limiting value is to be taken as the greater of the two. The upper limit for the throat thickness is, in general, to be as required by *Table 2.4.4 Throat thickness limits*. Throat thicknesses above this limit will be specially considered.

Table 2.4.4 Throat thickness limits

Item	Throat thickness mm	
	Minimum	Maximum
(1) Double continuous welding	$0{,}21t_p$	$0{,}44t_p$
(2) Intermittent welding	$0{,}27t_p$	$0{,}44t_p$ or 4,5
(3) All welds, overriding minimum:		
(a) Plate thickness $t_p \leq 7{,}5$ mm		
Hand or automatic welding	3,0	—
Automatic deep penetration welding	3,0	—
(b) Plate thickness $t_p \geq 7{,}5$ mm		
Hand or automatic welding	3,25	—
Automatic deep penetration welding	3,0	—

Note 1. In all cases the limiting value is to be taken as the greatest of the applicable values above.

Note 2. Where t_p exceeds 25 mm, the limiting values may be calculated using a notional thickness equal to 0,4 (t_p + 25) mm.

Note 3. The maximum throat thicknesses shown are intended only as a design limit for the approval of fillet welded joints. Any welding in excess of these limits is to be to the Surveyor's satisfaction.

4.7 Single sided welding

4.7.1 Temporary backing bars for single sided welding may be austenitic stainless steel, glass tape, ceramic, or anodized aluminium of the same material as the base metal. Backing bars are not to be made of copper to avoid weld contamination and corrosion problems.

4.7.2 Temporary backing bars are to be suitably grooved in way of the weld to ensure full penetration.

4.8 Double continuous fillet welding

4.8.1 Where double continuous fillet welding is proposed the throat thickness is to be in accordance with *Pt 7, Ch 2, 4.5 Fillet welds 4.5.1* taking $\left(\frac{d}{s}\right)$ equal to 1.

4.8.2 The impact area referred to in *Pt 7, Ch 2, 4.8 Double continuous fillet welding 4.8.5* and *Pt 7, Ch 2, 4.9 Intermittent fillet welding (staggered/chain) 4.9.1* is defined as the area of the hull that, in normal design operation of the craft, will be subject to loads of sufficient magnitude and velocity for slamming to occur on a regular basis. Areas where conditions for slamming occur incidentally are not considered as impact areas.

4.8.3 In the impact area, for welding arrangements where $t_p \leq$ 8mm and the requirements of *Pt 7, Ch 2, 4.5 Fillet welds* (considering $\frac{d}{s} = 1$) and *Pt 7, Ch 2, 4.6 Throat thickness limits* are complied with, it is permitted to reduce the length of the weld to not less than 80 per cent of the total length of a theoretical double continuous weld joining the elements in the arrangement. Welding is to be by an intermittent staggered arrangement, *see Figure 2.4.3 Overlapping intermittent staggered welding*. This requirement does not supersede others relating to end connections.

Figure 2.4.3 Overlapping intermittent staggered welding

4.8.4 The slamming zone area referred to in *Pt 7, Ch 2, 4.8 Double continuous fillet welding 4.8.2* is defined as the region where the operational non-displacement mode pressures exceed the operational displacement mode pressures.

4.8.5 Double continuous fillet welding is to be adopted in the following locations and may be used elsewhere if desired:

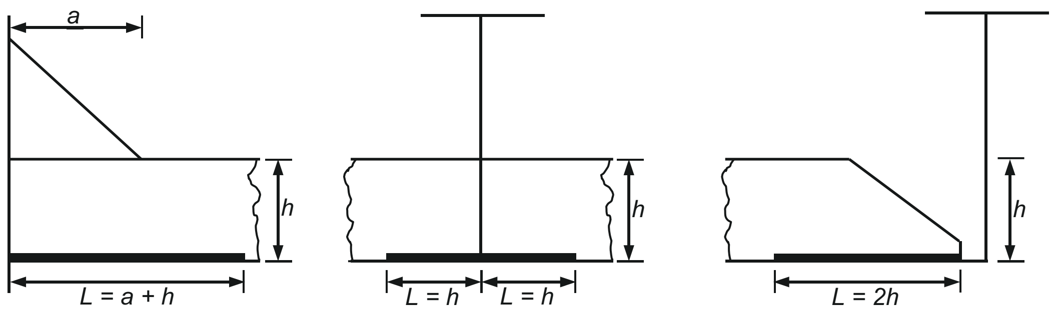
(a) Boundaries of weathertight decks and erections, including hatch coamings, companionways and other openings.
(b) Boundaries of tanks, watertight compartments and gastight compartments or in spaces or locations where condensation, spray or leakage water can accumulate.
(c) Main engine seatings.
(d) Bottom framing structure in way of machinery and jet room spaces of high speed craft as appropriate.
(e) The side and bottom shell structure in the impact area of high speed craft (*see Pt 7, Ch 2, 4.8 Double continuous fillet welding 4.8.3*).
(f) The underside of the cross-deck structure in the impact area of high speed multi-hull craft.
(g) Structure in way of ride control systems, stabilisers, foils, lifting devices, thrusters, bilge keels, foundations and other areas subject to high stresses.
(h) The shell structure in the vicinity of the propeller blades.
(i) Stiffening members to plating in way of end connections, scallops and of end brackets to plating in the case of lap connections.
(j) Primary and secondary members to plating in way of end connections, and end brackets to plating in the case of lap connections.
(k) Face flats to webs of built-up/fabricated stiffening members in way of knees/end brackets and for a distance beyond such knees/end brackets of not less than the web depth of stiffener in way.
(l) Locations where double continuous welding is required to qualify assumptions used in structural calculations, e.g. weld of girder flange in way of large cutout in the web.

4.8.6 In all locations where double continuous fillet welds are required, the fillet welds shall be continued around the ends of stiffeners or cut-outs to seal all edges.

4.8.7 Where intermittent welding is permitted, the length of double continuous fillet welding required in way of primary and secondary member end connections to plating is as shown in *Pt 7, Ch 2, 4.8 Double continuous fillet welding 4.8.8* and is not to be less than the greater of the following:

- the web depth of the smaller stiffening member extending either side of a stiffener crossing (weld length is required on both sides of the crossing members);
- twice the height of the stiffening member extending from either end of the stiffener if the stiffener is sniped;
- the height of the stiffening member plus the leg length of the attached bracket if the stiffener is bracketed; or
- 0,1 x stiffener span.

4.8.8 Proposals to reduce the double continuous weld lengths for secondary members may be specially considered provided that supporting documentation is submitted which considers effects such as strength, stiffness and dynamic loading frequency and other fatigue aspects.



h = secondary member depth
a = bracket arm length
L = required depth of double continuous weld. In no case is *L* to be less than 0,1 x stiffener span

Figure 2.4.4 Extent of double continuous welding at end connections of primary and secondary members

4.9 Intermittent fillet welding (staggered/chain)

4.9.1 Staggered or chain intermittent welding may be used, outside of the impact area in the side and bottom shell or the underside of the crossdeck structure of high speed craft. Supporting evidence is to be provided and agreed by LR demonstrating that no intermittent welding is applied in the impact areas of high speed craft, *see* Lloyd's Register Guidance Note – *Extent of double continuous welding for special service craft*. Consideration should be given to the relevant service area notation, service type notation and craft type notation.

4.10 Connections of primary structure

4.10.1 Depending on the structural design of the joint and design loads on the primary member, full penetration welding of flanges and web plates may be required to attain full section properties in the end connections of primary members. *See also Pt 6, Ch 3, 1.22 Primary member end connections*. Otherwise weld factors for the connections of primary structure are given in *Table 2.4.3 Weld factors*.

4.10.2 The weld connection to shell, deck or bulkhead is to take account of the material lost in the notch where longitudinals or stiffeners pass through the member. Where the width of notch exceeds 15 per cent of the stiffener spacing, the weld factor is to be multiplied by:

$$\frac{0,85 \times \text{stiffener spacing}}{\text{length of web plating between notches}}$$

4.10.3 Where direct calculation procedures have been adopted, the weld factors for the 0,1 x overall length at the ends of the members will be considered in relation to the calculated loads.

4.11 Primary and secondary member end connection welds

4.11.1 Welding of end connections of primary members is to be such that the area of welding is not less than the cross-sectional area of the member, and the weld factor is to be not less than 0,34 in tanks or 0,27 elsewhere.

4.11.2 The welding of secondary member end connections is to be not less than as required by *Table 2.4.5 Secondary member end connections welds*. Where two requirements are given the greater is to be complied with.

4.11.3 The area of weld, A_w, is to be applied to each arm of the bracket or lapped connection.

4.11.4 Where a longitudinal strength member is cut at a primary support and the continuity of strength is provided by brackets, the area of weld is to be not less than the cross-sectional area of the member.

4.12 Weld connection of strength deck plating to sheerstrake

4.12.1 The weld connection of strength deck plating to sheerstrake is to be by double continuous fillet welding with a weld factor of 0,44. The welding procedure, including joint preparation, is to be specified and the procedure qualified and approved for individual Builders.

Table 2.4.5 Secondary member end connections welds

Connection	Weld area, A_w in cm^2	Weld factor
(1) Stiffener welded direct to plating	$0{,}25A_s$ or 6,5 cm^2 whichever is the greater	0,34
(2) Bracketless connection of stiffeners or stiffener lapped to bracket or bracket lapped to stiffener:		
(a) in dry space	$1{,}2\sqrt{Z}$	0,27
(b) in tank	$1{,}4\sqrt{Z}$	0,34
(c) main frame to tank side bracket in 0,15 L_R forward	as (a) or (b)	0,34
(3) Bracket welded to face of stiffener and bracket connection to plating	-	0,34
(4) Stiffener to plating for 0,1 x span at ends, or in way of the end bracket if that be greater	-	0,34
Symbols		
A_s = cross section area of the stiffener, in cm^2		
A_w = the area of the weld, in cm^2, and is calculated as total length of weld, in cm, x throat thickness, in cm		
Z = the section modulus, in cm^3, of the stiffener on which the scantlings of the end bracket are based		
Note For maximum and minimum weld fillet sizes, *see Table 2.4.4 Throat thickness limits*.		

4.13 Air and drain holes

4.13.1 Air and drain holes are to be kept clear of the toes of brackets, etc. Openings are to be well rounded with smooth edges, *see also* LR's *Guidance Notes for Structural Details*.

4.14 Notches and scallops

4.14.1 Notches and scallops are to be kept clear of the toes of brackets, etc. Openings are to be well rounded with smooth edges. Details of scallops are shown in *Figure 13.2.1 Weld dimensions and types* in Chapter 13 of the Rules for Materials.

4.14.2 Scallops are to be of such a size, and in such a position that a satisfactory weld can be made around the ends of openings.

4.15 Watertight collars

4.15.1 Watertight collars are to be fitted, where stiffeners are continuous through watertight or oiltight boundaries, *see also* LR's *Guidance Notes for Structural Details*.

4.16 Lug connections

4.16.1 The area of the weld connecting secondary stiffeners to primary structure in the bottoms of the hulls and cross-deck structure in areas subjected to impact pressures is to be not less than the shear area from the Rules. This area is to be obtained by fitting two lugs or by other equivalent arrangements. Some typical lug connections are shown in *Figure 2.4.5 Typical lug connections* and *Figure 3.1.7 Cut-outs and connections* in Chapter 3.

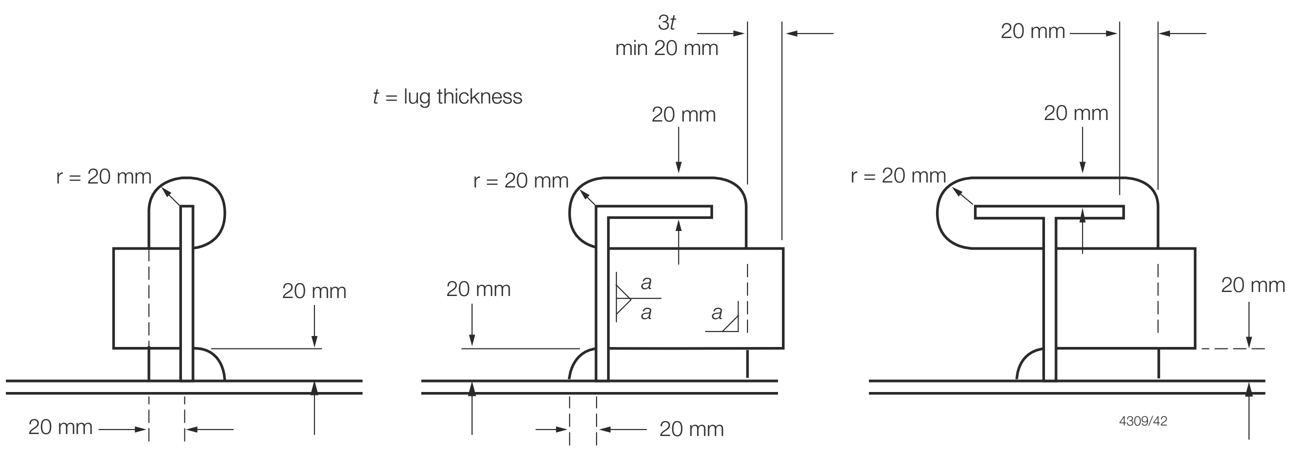


Figure 2.4.5 Typical lug connections

4.16.2 Lugs or tripping brackets are to be fitted where shell longitudinals are continuous through web frames in way of highly stressed areas of the side shell (e.g. in way of fenders, etc).

4.16.3 Lugs or tripping brackets are also to be fitted where continuous secondary stiffeners are greater than half the depth of the primary stiffeners.

4.17 Insert plates

4.17.1 Where thick insert plates are butt welded to thin plates, the edge of the thick plate may require to be tapered. The slope of the taper is generally not to exceed one in three.

4.17.2 The corners of insert plates are to be suitably radiused.

4.18 Doubler plates

4.18.1 Doubler plates are to be avoided in areas where corrosion may be a problem and access for inspection and maintenance is limited.

4.18.2 Where doubler plates are fitted, they are to have well radiused corners and the perimeter is to be continuously welded. Large doubler plates are also to be suitably slot welded, the details of which are to be submitted for consideration.

4.19 Joint preparation

4.19.1 Typical butt joints are shown in *Table 2.4.1 Typical joint preparations for TIG welding of aluminium alloys* and *Table 2.4.2 Typical joint preparations for semi-automatic MIG welding*, *see also* LR's *Guidance Notes for Structural Details*.

4.20 Construction tolerances

4.20.1 The minimum requirements for construction tolerances are to be in accordance with *Pt 3, Ch 1, 8 Building tolerances and associated repairs*.

4.21 Riveting of light structure

4.21.1 Where it is proposed to adopt riveted construction, full details of the rivets or similar fastenings, including mechanical test results, are to be indicated on the construction plans submitted for approval or a separate riveting schedule is to be submitted.

4.21.2 Samples may be required of typical riveted joints made by the Builder under representative construction conditions and tested to destruction in the presence of the Surveyor in shear, tension, compression or peel at LR's discretion.

4.21.3 Where riveting strength data sheets have been issued by a recognised Authority, the values quoted in these sheets will normally be accepted for design purposes.

4.21.4 Where two dissimilar metals are to be joined by riveting, precautions are to be taken to eliminate electrolytic corrosion to LR's satisfaction, and where practicable, the arrangements should be such as to enable the joint to be kept under observation at each survey without undue removal of lining and other items.

4.21.5 Where a sealing compound is used to obtain an airtight or watertight joint, details are to be submitted of its proposed use and of any tests made or experience gained in its use for similar applications.

4.21.6 Aluminium alloy rivets in accordance with *Ch 8, 2 Aluminium alloy rivets* of the Rules for Materials are to be used where practicable. However, in the case of composite structures, including steel and GRP, consideration will be given to the use of steel rivets. In such cases, the mating surfaces are to be coated with a sealing paint.

4.21.7 Sealing paints or compounds are not to be used with hot driven rivets.

4.22 Chemical bonding of structure

4.22.1 Where chemical bonding of aluminium alloy of any load-bearing structure is proposed, details of the materials and the processes to be used are to be submitted for approval. These details are to include test results of samples manufactured under LR survey under workshop conditions to verify the strength, ageing effects and moisture resistance.

4.22.2 The adhesive manufacturer's recommendations in respect of the specified jointing system, comprising preparation of the surfaces to be adhered, the adhesive, bonding and curing processes, are to be strictly followed as variation of any step can severely affect the performance of the joint.

4.22.3 Meticulous preparation is essential where the joint is to be made by chemical bonding. The method of producing bonded joints is to be documented so that the process is repeatable after the procedure has been properly established.

4.22.4 Bonded joints are suitable for carrying shear loads, but are not in general to be used in tension or where the load causes peeling or other forces tending to open the joint. Loads are to be carried over as large an area as possible.

4.22.5 Bonded joints are to be suitably supported after assembly for the period necessary to allow the optimum bond strength of the adhesive to be to be developed. Entrained air pockets are to be avoided.

4.22.6 The use of adhesives for main structural joints is not to be contemplated unless considerable testing has established its validity, including environmental testing and fatigue testing where considered necessary by LR.

4.23 Triaxial stress considerations

4.23.1 Particular care is to be taken to avoid triaxial stresses which may result from poor joint design. Detailed joint design is of particular importance in aluminium structures more so than many other materials. Some recommendations in this respect are contained in LR's *Guidance Notes for Structural Details*.

4.24 Butt straps

4.24.1 In general, the scantling derivation of welded structures are to be determined using the mechanical properties of the aluminium alloy in the welded condition in accordance with *Pt 7, Ch 2, 2.4 Mechanical properties for design*. However, where stiffeners are butt welded, special consideration will be given to the use of suitable butt straps on the flanges which sufficiently reinforce the area of the weld to allow the scantlings to be determined using the unwelded mechanical properties. The butt weld is to be completed and generally made flush with the flange of the stiffening member before the butt strap is fitted and the butt strap weld is to be continuous. Where this jointing method is proposed, the scantlings, arrangements and locations of all joints and butt straps are to be submitted. Additionally, LR may require mechanical tests to be carried out to demonstrate the effectiveness of such arrangements.

4.25 Extruded `planking'

4.25.1 Joints between adjacent extruded aluminium alloy planking, and the attachment of the planking to the supporting structure is in general to be by means of continuous welding.

4.25.2 The planking is generally not to be included in the determination of the section properties for both section modulus and inertia. However, special consideration will be given to the inclusion of such materials on the basis of the efficiency of the connection to the supporting structure.

4.26 Aluminium/steel transition joints

4.26.1 Provision is made in this Section for explosion bonded composite aluminium/steel transition joints used for connecting aluminium structures to steel plating. Such joints are to be used in accordance with the manufacturer's requirements, *see also Ch 8, 4 Aluminium/steel transition joints*of the Rules for Materials.

4.26.2 Transition joints are to be manufactured by an approved producer in accordance with an approved specification which is to include the maximum temperature allowable at the interface during welding.

4.26.3 The aluminium material is to comply with the requirements of *Pt 7, Ch 2, 2 Materials* and the steel is to be of an appropriate grade complying with the requirements of *Ch 3, 2 Normal strength steels for ship and other structural applications*of the Rules for Materials.

4.26.4 Alternative materials which comply with International, National or proprietary specifications may be accepted provided that they give equivalence to the requirements of *Pt 7, Ch 2, 4.26 Aluminium/steel transition joints 4.26.3* or are approved for a specific application.

4.26.5 Intermediate layers between the aluminium and steel may be used, in which case the material of any such layer is to be specified by the manufacturer and is to be recorded in the approval certificate. Any such intermediate layer is then to be used in all production transition joints.

4.26.6 Bimetallic joints where exposed to seawater or used internally within wet spaces are to be suitably protected to prevent galvanic corrosion.

4.27 Aluminium/wood connection

4.27.1 To minimise corrosion of aluminium when in contact with wood in a damp or marine environment the timber is to be primed and painted in accordance with good practice. Alternatively the surface of the aluminium in contact with the timber is to be coated with a substantial thickness of a suitable sealant.

4.27.2 Timbers such as western red cedar, oak and chestnut are not, unless well seasoned, to be directly in contact with aluminium.

4.27.3 Timber preservatives of the following types should be avoided: copper napthanate, copper-chrome-arsenate, borax-boric acid.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull craft of aluminium construction as defined in *Pt 1, Ch 2, 2 Scope of the Rules*.

1.2 General

1.2.1 The formulae contained within this Chapter are to be used in conjunction with the design loadings from *Pt 5 Design and Load Criteria* to determine the Rule scantling requirements.

1.3 Direct calculations

1.3.1 Where the craft is of unusual design, form or proportions, or where the speed of the craft exceeds 60 knots the scantlings are to be determined by direct calculation.

1.3.2 The requirements of this Chapter may be modified where direct calculation procedures are adopted to analyse the stress distribution in the primary structure.

1.4 Equivalents

1.4.1 Lloyd's Register (hereinafter referred to as 'LR') will consider direct calculations for the derivation of scantlings as an alternative and equivalent to those derived by Rule requirements in accordance with *Pt 3, Ch 1, 3 Equivalents*.

1.5 Symbols and definitions

1.5.1 The symbols used in this Chapter are defined below and in the appropriate Section:

k_a = alloy factor

= $125/\sigma_a$

l = stiffener overall length, in metres

l_e = effective span length, in metres, as defined in *Pt 7, Ch 3, 1.19 Determination of span point*

p = design pressure, in kN/m^2, as given in *Pt 5 Design and Load Criteria*

s = stiffener spacing, in mm

t_p = plating thickness, in mm

A_w = shear area of stiffener web, in cm^2

B = moulded breadth of craft, in metres, as defined in *Pt 3, Ch 1, 6 Definitions*

E = modulus of elasticity, in N/mm^2

I = moment of inertia, in cm^4

L_R = Rule length of craft, in metres, as defined in *Pt 3, Ch 1, 6 Definitions*

Z = section modulus of the stiffening member, in cm^3

β = panel aspect ratio correction factor as defined in *Pt 7, Ch 3, 1.15 Aspect ratio correction*

γ = convex curvature correction factor as defined in *Pt 7, Ch 3, 1.14 Convex curvature correction*

σ_a = guaranteed minimum 0,2 per cent proof stress of the alloy in the welded condition, in N/mm^2, *see also Pt 7, Ch 2, 2.4 Mechanical properties for design 2.4.2*

τ_a = $\dfrac{\sigma_a}{\sqrt{3}}$.

1.6 Rounding policy for Rule plating thickness

1.6.1 Where plating thicknesses as determined by the Rules require to be rounded then this is to be carried out to the nearest full or half millimetre, with thicknesses 0,75 and 0,25 being rounded up.

1.7 Dimensional tolerance

1.7.1 Dimensional tolerances for materials are to be in accordance with *Ch 8 Aluminium Alloys*of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials), or an acceptable National or International Standard.

1.7.2 The under thickness tolerance acceptable for classification is to be considered as the lower limit of a range of thickness tolerance which could be found in the normal production of a conventional rolling mill manufacturing material, on average, to the nominal thickness.

1.7.3 The Owners and Builders may agree in individual cases whether they wish to specify a more stringent under thickness tolerance than that given in *Pt 7, Ch 3, 1.7 Dimensional tolerance 1.7.2*.

1.7.4 The minus tolerance on sections (except for wide flats) is to be in accordance with a National or International Standard.

1.7.5 The thickness of plates and strip is to be measured at random locations whose distance from an edge is to be at least 25 mm. Local surface depressions resulting from imperfections and ground areas resulting from the elimination of defects may be disregarded provided that they are in accordance with the requirements of a National or International Standard.

1.7.6 The responsibility for maintaining the required tolerances and making the necessary measurements rests with the manufacturer/Builder. Occasional checking by the Surveyor does not absolve the manufacturer/Builder from the responsibility.

1.8 Material properties

1.8.1 The basic grade of aluminium alloy is taken as marine grade 5083-0 with the following mechanical properties:

	N/mm^2
0,2 per cent proof stress (minimum)	125

Tensile strength	260
Modulus of elasticity	69 x 10^3

1.8.2 Where other alloy grades with differing mechanical properties are to be used, due allowance is given in the determination of the Rule requirement for plating thickness, section modulus, inertia and cross-sectional area by use of the following correction factors:

(a) Plating thickness factor = $\sqrt{k_a}$

(b) Section modulus and cross section area factor = k_a

where k_a is as defined in *Pt 7, Ch 3, 1.5 Symbols and definitions 1.5.1*.

1.9 High strength sheet and plate

1.9.1 Particular attention is to be given to the welding procedures for the welding of high strength sheet and plate. The 0,2 per cent yield strength values in the welded condition will, in general, be significantly less than in the unwelded condition. These reduced values are to be used in the determination of the Rule scantlings.

1.10 High strength extrusions

1.10.1 The requirements of *Pt 7, Ch 3, 1.9 High strength sheet and plate* are to be complied with. However, special consideration will be given to the use of un-welded strength properties for use in the determination of the Rule scantlings provided that suitable compensation is provided in way of welding on the face of the stiffener. This compensation can be provided by butt-straps or other acceptable arrangements, *see also Pt 7, Ch 2, 4.25 Extruded `planking*'.

1.10.2 The application of high strength extrusions is in general limited to superstructures, deckhouses, decks and bulkheads. Special consideration will be given to their use in other areas.

1.10.3 Butt welds and seams are to be carefully positioned clear of areas of high stress and where practicable are to be orientated parallel to the direction of the main stresses.

1.11 Effective width of attached plating

1.11.1 The effective geometric properties of rolled or built sections are to be calculated directly from the dimensions of the section and associated effective area of attached plating. Where the web of the section is not normal to the actual plating, and the angle exceeds 20°, the properties of the section are to be determined about an axis parallel to the attached plating.

1.11.2 For stiffening members, the geometric properties of rolled or built sections are to be calculated in association with an effective area of attached load bearing plating of thickness t_p, in mm and a breadth b_e, in mm, b_e is as defined in *Pt 7, Ch 3, 1.11 Effective width of attached plating 1.11.3* and *Pt 7, Ch 3, 1.11 Effective width of attached plating 1.11.4*.

1.11.3 The effective width of attached plating to secondary members b_e is to be taken as $2t_p\sqrt{E/\sigma_a}$ but not greater than s. σ_a is not to be taken as greater than 169 N/mm^2 for aluminum alloy. E, s and σ_a are as defined in *Pt 7, Ch 3, 1.5 Symbols and definitions 1.5.1*.

1.11.4 The effective breadth of attached plating to primary support members (girders, transverses, webs, etc.) b_e is to be taken as bf, where b and f are as defined in *Pt 3, Ch 2, 3.2 Geometric properties of sections 3.2.1*.

1.11.5 Where primary stiffening members support areas of plating of the extruded plank type, or the floating frame system is used, the effect of the plating attached to the secondary stiffening members is to be ignored when calculating the actual section modulus and inertia of the primary stiffening members, i.e. the full section modulus and inertia are to be provided by the primary stiffening member only, *see also Pt 7, Ch 2, 4.26 Aluminium/steel transition joints*.

1.12 Other materials

1.12.1 Special consideration will be given to the use of materials other than aluminium alloy. Details of the type of material, the specification to which it was manufactured and its mechanical properties are to be submitted for appraisal.

1.13 Fibre reinforced plastic (FRP)

1.13.1 The use of FRP in construction is to be in accordance with *Pt 8 Hull Construction in Composite*.

1.14 Convex curvature correction

1.14.1 The thickness of plating as determined by the Rules may be reduced where significant curvature exists between the supporting members. In such cases a plate curvature correction factor may be applied:

γ = plate curvature factor

= 1 - *h*/*s*, and is not to be taken as less than 0,7

h = the distance, in mm, measured perpendicularly from the chord length *s* (i.e. spacing) to the highest point of the curved plating arc between the two supports.

See Figure 3.1.1 Convex curvature.

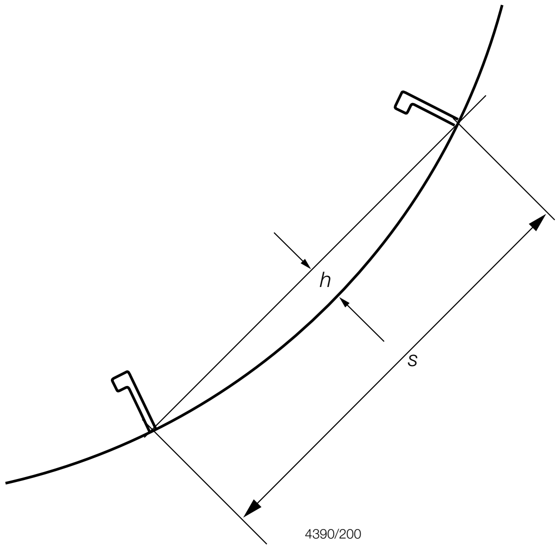


Figure 3.1.1 Convex curvature

1.15 Aspect ratio correction

1.15.1 The thickness of plating as determined by the Rules may be reduced when the panel aspect ratio is taken into consideration. In such cases a panel aspect ratio correction factor may be applied:

β = aspect ratio correction factor

= $A_R(1 - 0{,}25A_R)$ for $A_R \leq 2$

= 1 for $A_R > 2$

where

A_R = panel aspect ratio

= panel length/panel breadth.

1.16 Plating general

1.16.1 The requirements for the thickness of plating, t_p, is, in general, to be in accordance with the following:

$$t_p = 22{,}4\, s\, \gamma\, \beta \sqrt{\frac{p}{f_\sigma \sigma_a}} \times 10^{-3} \text{ mm}$$

where

f_σ = limiting bending stress coefficient for the plating element under consideration is given in *Table 7.3.1 Limiting stress coefficients for local loading* in Chapter 7.

s, γ, β, p, σ_a are as defined in *Pt 7, Ch 3, 1.5 Symbols and definitions 1.5.1*.

1.17 Stiffening general

1.17.1 The requirements for section modulus, inertia and web area of stiffening members are in general to be in accordance with the following:

(a) Section modulus:

$$Z = F_Z \frac{psl_e^2}{f_\sigma \sigma_a} \quad \text{cm}^3$$

where

Φ_Z = section modulus coefficient dependent on the loading model assumption taken from *Table 3.1.1 Section modulus, inertia and web area coefficients*

f_σ = limiting bending stress coefficient for stiffening member given in *Table 7.3.1 Limiting stress coefficients for local loading* in Chapter 7.

p, s, l_e and σ_a are as defined in *Pt 7, Ch 3, 1.5 Symbols and definitions*.

(b) Inertia:

$$I = F_I f_\delta \frac{psl_e^3}{E} \times 100 \quad \text{cm}^4$$

where

Φ_I = inertia coefficient dependent on the loading model assumption taken from *Table 3.1.1 Section modulus, inertia and web area coefficients*

f_δ = limiting deflection coefficient for stiffener member given in *Table 7.2.1 Limiting deflection ratio* in Chapter 7.

p, s, l_e, and E are as defined in *Pt 7, Ch 3, 1.5 Symbols and definitions 1.5.1*.

(c) Web area:

$$A_w = F_A \frac{psl_e}{100 f_\tau \tau_a} \quad \text{cm}^2$$

where

Φ_A = web area coefficient dependent on the loading model assumption taken from *Table 3.1.1 Section modulus, inertia and web area coefficients*

f_τ = limiting shear stress coefficient for stiffener member given in *Table 7.3.1 Limiting stress coefficients for local loading*

p, s, l_e, and τ_a are as defined in *Pt 7, Ch 3, 1.5 Symbols and definitions 1.5.1*.

1.18 Geometric properties and proportions of stiffener sections

1.18.1 From structural stability and local buckling considerations, the proportions of stiffening members are, in general, to be in accordance with *Table 3.1.2 Stiffener proportions*.

1.19 Determination of span point

1.19.1 The effective length of span, l_e, of a stiffening member is generally less than the overall length, l , by an amount which depends on the design of the end connections. The span points, between which the value of l_e is measured, are to be determined as follows:

(a) For rolled or built-up secondary stiffening members:

The span point is to be taken at the point where the depth of the end bracket, measured from the face of the secondary stiffening member, is equal to the depth of the member, *see Figure 3.1.2 Span points*. Where there is no end bracket, the span point is to be measured between primary member webs.

(b) For primary support members:

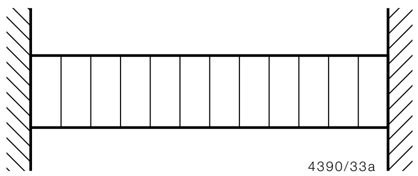
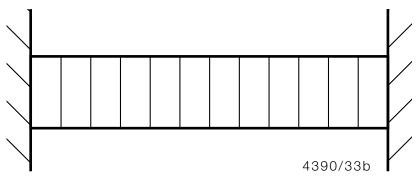
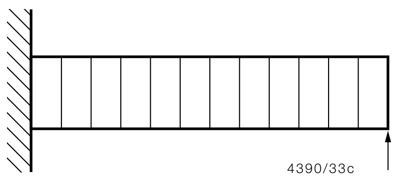
The span point is to be taken at a point distant, b_e from the end of the member, where

$$b_e = b_b\left(1 - \frac{d_w}{d_b}\right)$$

where b_e, b_b, d_w and d_B are as shown in *Figure 3.1.2 Span points*.

1.19.2 Where the stiffener member is inclined to a vertical or horizontal axis and the inclination exceeds 10°, the span is to be measured along the member.

Table 3.1.1 Section modulus, inertia and web area coefficients

Load Model	Position			Position	Web area coefficient Φ_A	Section modulus coefficient Φ_Z	Inertia coefficient Φ_I	Application
	1	2	3					
(a)				1	1/2	1/12	-	Primary and other members where the end fixity is considered encastre
				2	-	1/24	1/384	
				3	1/2	1/12	-	
(b)				1	1/2	1/10	-	Local, secondary and other members where the end fixity is considered to be partial
				2	-	1/10	1/288	
				3	1/2	1/10	-	
(c)				1	5/8	1/8	-	Various
				2	-	9/128	1/185	
				3	3/8	-	-	

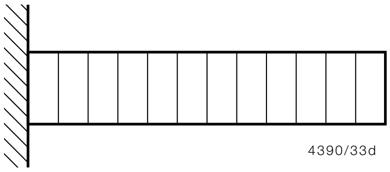
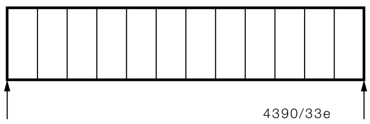
(d)		1	1	1/2	-	Various
		2	-	-	-	
		3	-	-	1/8	
(e)		1	1/2	-	-	Hatch covers, glazing and other members where the ends are simply supported
		2	-	1/8	5/384	
		3	1/2	-	-	

Table 3.1.2 Stiffener proportions

Type of stiffener	Requirement
(1) Flat bar	Minimum web thickness: $t_w = d_w/15 \geq 3\text{mm}$
(2) Rolled or built sections	(a) Minimum web thickness: $t_w = d_w/50 \geq 3\text{mm}$ (b) Maximum unsupported face plate (or flange) width: $b_f = 16t_f$
Symbols	
t_w = web thickness of stiffener with unstiffened webs, in mm d_w = web depth of stiffener, in mm b_f = face plate (or flange) unsupported width, in mm t_f = face plate (or flange) thickness, in mm	

1.19.3 Where the stiffening member is curved then the span is to be taken as the effective chord length between span points.

1.19.4 Where there is a pronounced turn of bilge, chine or the structure is significantly pitched, the span may be measured as in *Figure 3.1.2 Span points*.

1.19.5 It is assumed that the ends of stiffening members are substantially fixed against rotation and displacement. If the arrangement of supporting structure is such that this condition is not achieved, consideration will be given to the effective span to be used for the stiffener.

1.20 Secondary member end connections

1.20.1 Secondary members, that is longitudinals, beams, frames and bulkhead stiffeners forming part of the hull structure, are to be effectively continuous and are to be suitably bracketed at their end connections. Where it is desired to adopt bracketless connections, the proposed arrangements will be individually considered, *see also Pt 7, Ch 2, 4.12 Weld connection of strength deck plating to sheerstrake* and *Table 2.4.5 Secondary member end connections welds* in Chapter 2.

1.20.2 Where bracketed end connections are fitted in accordance with these requirements, they may be taken into account in determining the effective span of the member.

1.20.3 The scantlings of secondary member end connections are to be in accordance with *Pt 7, Ch 3, 1.21 Scantlings of end brackets*.

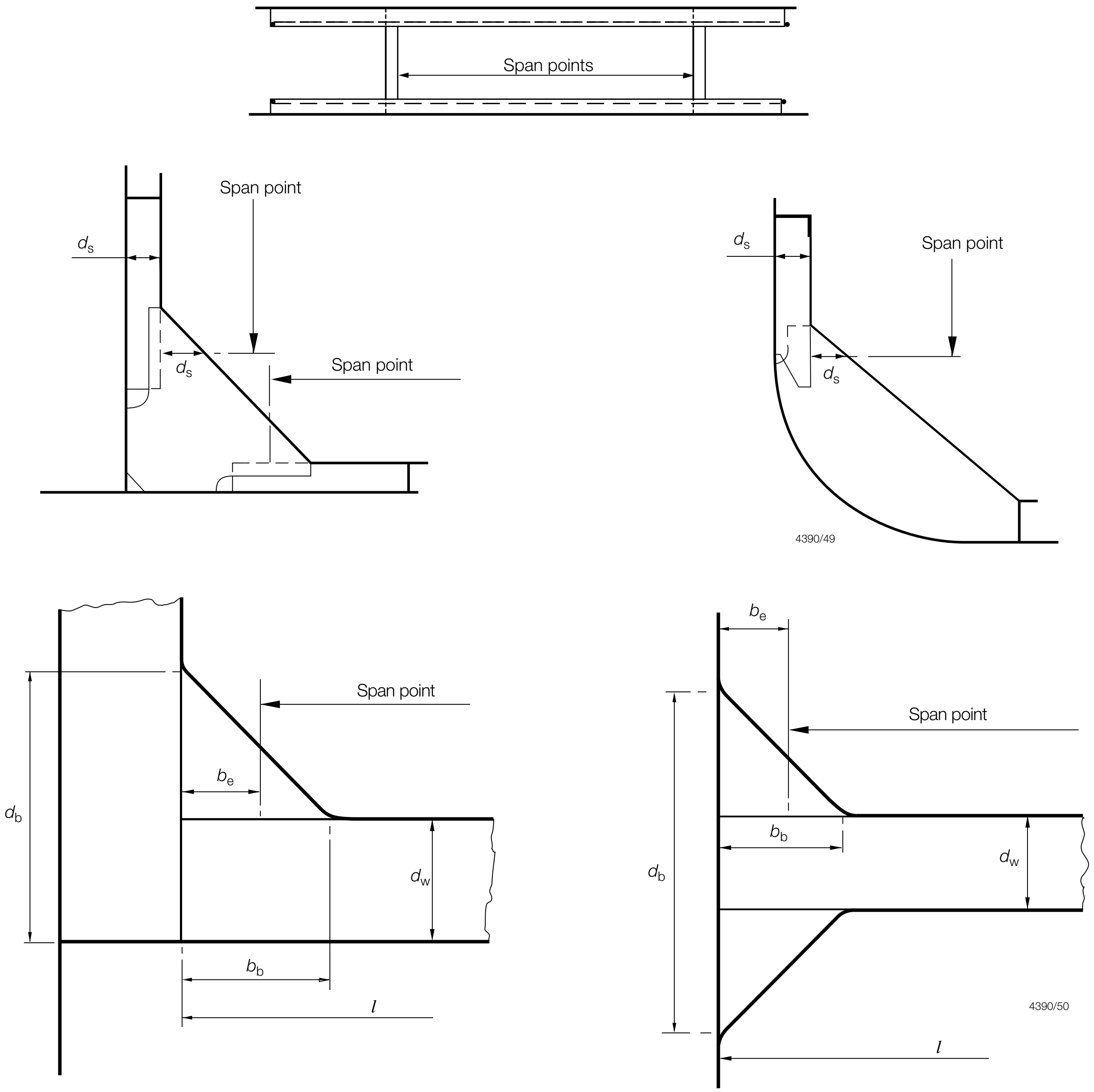


Figure 3.1.2 Span points

1.21 Scantlings of end brackets

1.21.1 Where a longitudinal strength member is cut at a primary support and the continuity of strength is provided by brackets, the scantlings of the end brackets are to be such that their section modulus and effective cross-sectional area are not less than those of the member. Care is to be taken to ensure correct alignment of the brackets on each side of the primary member.

1.21.2 In other cases the scantlings of the bracket are to be based on the modulus as follows:

(a) Bracket connecting stiffener to primary member - modulus of the stiffener.

(b) Bracket at the head of a main transverse frame where frame terminates - modulus of the frame.
(c) Brackets connecting lower deck beams or longitudinals to the main frame in the forward $0,5L_R$ - modulus of the frame.
(d) Elsewhere - the lesser modulus of the members being connected by the bracket.

1.21.3 The web thickness and face flat area of end brackets are not in general to be less than those of the connecting stiffeners. Additionally, the stiffener proportion requirements of *Pt 7, Ch 3, 1.18 Geometric properties and proportions of stiffener sections* are to be satisfied.

1.21.4 Typical arrangements of stiffener end brackets are shown diagrammatically in *Figure 3.1.3 Stiffener end brackets*.

1.21.5 The lengths, *a* and *b* of the arms are to be measured from the plating to the toe of the bracket and are to be such that:

(a) $a + b \geq 2,0\, l_b$
(b) $a \geq 0,8\, l_b$
(c) $b \geq 0,8\, l_b$

where *a* and *b* are the actual lengths of the two arms of the bracket, in mm, measured from the plating to the toe of the bracket.

$$l_b = 90\left(2\sqrt{\frac{Z}{14+\sqrt{Z}}} - 1\right) \text{ mm}$$

Z = the section modulus of the secondary member, in cm^3

In no case is l_b to be taken as less than twice the web depth of the stiffener on which the bracket scantlings are to be based.

1.21.6 The free edge of the bracket is to be stiffened where any of the following apply:

(a) The section modulus, *Z*, exceeds 500 cm^3.
(b) The length of free edge exceeds 40 times the bracket thickness.
(c) The bracket is fitted at the lower end of main transverse side framing.

1.21.7 Where a face flat is fitted, its breadth, b_f, is to be not less than:

$$b_f = 30\left(1 + \frac{Z}{1000}\right) \text{ mm}$$

but not less than 40 mm

1.21.8 Where the edge is stiffened by a welded face flat, the cross-sectional area of the face flat is to be not less than:

(a) $0,017\, k_a\, b_f\, T_B$ cm^2 for offset edge stiffening.
(b) $0,014\, k_a\, b_f\, T_B$ cm^2 for symmetrically placed stiffening.

b_f = breadth of face flat, in mm

T_B = the thickness of the bracket, in mm

k_a = is as defined in *Pt 7, Ch 3, 1.5 Symbols and definitions 1.5.1*.

1.21.9 Where the stiffening member is lapped onto the bracket, the length of overlap is to be adequate to provide for the required area of welding. In general, the length of overlap is not to be less than $10\sqrt{Z}$, or the depth of stiffener, whichever is the greater.

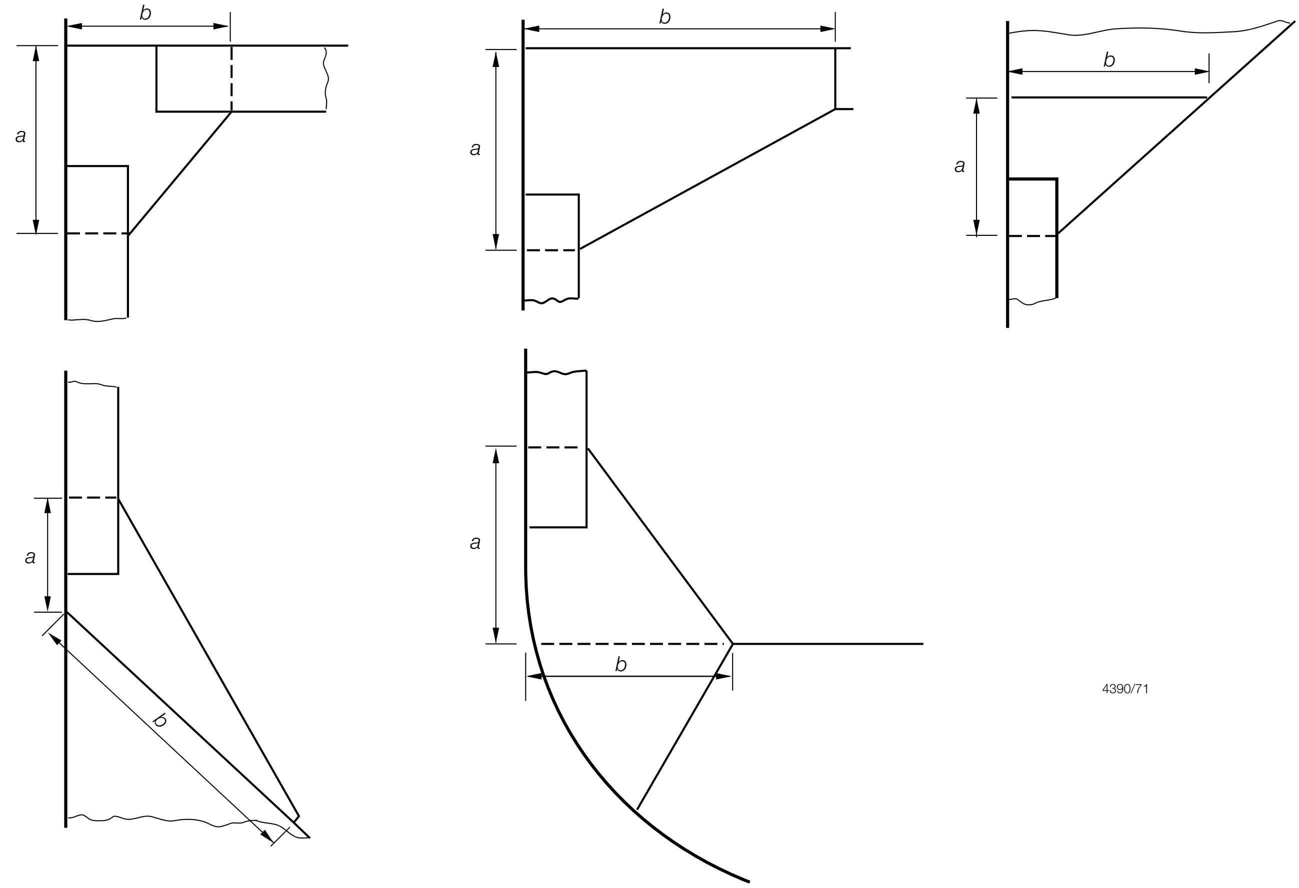


Figure 3.1.3 Stiffener end brackets

1.21.10 Where the free edge of the bracket is hollowed out, it is to be stiffened or increased in size to ensure that the modulus of the bracket through the throat is not less than that of the required straight edged bracket.

1.21.11 The arrangement of the connection between the stiffener and the bracket is to be such that at no point in the connection is the actual modulus reduced to less than that of the stiffener with associated plating.

1.21.12 The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint.

1.22 Primary member end connections

1.22.1 The requirements for section modulus and inertia (if applicable) of primary members are given in the appropriate Chapter. The scantling requirements for primary member end connections in dry spaces and in tanks of all craft types are generally to comply with the requirements of *Pt 7, Ch 3, 1.21 Scantlings of end brackets*, taking Z as the section modulus of the primary member.

1.22.2 Primary members are to be so arranged as to ensure effective continuity of strength, and abrupt changes of depth or section are to be avoided. Where members abut on both sides of a bulkhead, or on other members, arrangements are to be made to ensure that they are in alignment. Primary members in tanks are to form a continuous line of support and wherever possible, a complete ring system.

1.22.3 The members are to have adequate lateral stability and web stiffening and the structure is to be arranged to minimise hard spots and other sources of stress concentration. Openings are to have well rounded corners and smooth edges and are to be located having regard to the stress distribution and buckling strength of the panel.

1.22.4 Primary members are to be provided with adequate end fixity by end brackets or equivalent structure. The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint and effective distribution of the load from the member.

1.22.5 Where the primary member is supported by structure which provides only a low degree of restraint against rotation, the member is generally to be extended beyond the point of support and thereafter tapered and/or scarfed into the adjacent structure over a distance generally not less than two frame spaces.

1.22.6 Where primary members are subject to concentrated loads, particularly if these are out of line with the member web, additional strengthening may be required.

1.22.7 The thickness of the bracket is to be not less than that of the primary member web. The free edge of the bracket is to be stiffened.

1.22.8 Where a deck girder or transverse is connected to a vertical member on the shell or bulkhead, the scantlings of the latter may be required to be increased to provide adequate stiffness to resist rotation of the joint.

1.22.9 Where a member is continued over a point of support, such as a pillar or pillar bulkhead stiffener, the design of the end connection is to be such as to ensure the effective distribution of the load into the support. Proposals to fit brackets of reduced scantlings, or alternative arrangements, will be considered.

1.22.10 Connections between primary members forming a ring system are to minimise stress concentrations at the junctions. Integral brackets are generally to be radiused or well rounded at their toes. The arm length of the bracket, measured from the face of the member, is to be not less than the depth of the smaller member forming the connection.

1.23 Tank boundary penetrations

1.23.1 Where structural members pass through the boundary of a tank, and leakage into the adjacent space could be hazardous or undesirable, full penetration welding is to be adopted for the members for at least 150 mm on each side of the boundary. Alternatively a small scallop of suitable shape may be cut in the member close to the boundary outside the compartment, and carefully welded all round.

1.24 Web stability

1.24.1 Primary members are to be supported by tripping brackets. The tripping brackets supporting asymmetrical sections are to be spaced no more than two secondary frames apart. The tripping brackets supporting symmetrical sections are to be spaced no more than four secondary frames apart.

1.24.2 Tripping brackets are in general required to be fitted at the toes of end brackets and in way of heavy or concentrated loads such as the heels of pillars. *See also* LR's *Guidance Notes for Structural Details*.

1.25 Openings in the web

1.25.1 Where openings are cut in the web, the depth of opening is not to exceed 50 per cent of the web depth, and the opening is to be so located that the edges are not less than 25 per cent of the web depth from the face plate. The length of opening is not to exceed the web depth or 60 per cent of the secondary member spacing, whichever is the greater, and the ends of the openings are to be equidistant from the corners of cut-outs for secondary members. Where larger openings are proposed, the arrangements and compensation required will be specially considered.

1.25.2 Openings are to have smooth edges and well rounded corners.

1.26 Continuity and alignment

1.26.1 The arrangement of material is to be such as will ensure structural continuity. Abrupt changes of shape or section, sharp corners and points of stress concentration are to be avoided.

1.26.2 Where members abut on both sides of a bulkhead or similar structure, care is to be taken to ensure good alignment.

1.26.3 Pillars and pillar bulkheads are to be fitted in the same vertical line wherever possible, and elsewhere arrangements are to be made to transmit the out of line forces satisfactorily. The load at head and heel of pillars is to be effectively distributed and arrangements are to be made to ensure the adequacy and lateral stability of the supporting members.

1.26.4 Continuity is to be maintained where primary members intersect and where the members are of the same depth, a suitable gusset plate is to be fitted, *see Figure 3.1.4 Primary member intersection*.

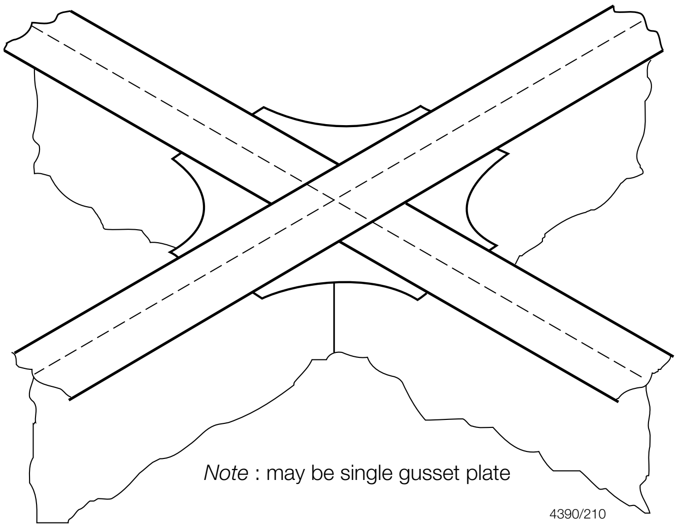


Figure 3.1.4 Primary member intersection

1.26.5 End connections of structural members are to provide adequate end fixity and effective distribution of the load into the supporting structure.

1.26.6 The toes of brackets, etc. are not to land on unstiffened panels of plating. Special care is to be taken to avoid notch effects at the toes of brackets, by making the toe concave or otherwise tapering it off, *see also* LR's *Guidance Notes for Structural Details*.

1.26.7 Particular attention is to be paid to the design of the end bracket toes in order to minimise stress concentrations. Sniped face plates which are welded onto the edge of primary member brackets are to be carried well around the radiused part of the bracket toe and are to incorporate a taper not exceeding one in three. Where sniped face plates are welded adjacent to the edge of primary member brackets, adequate cross sectional area is to be provided through the bracket toe at the end of the snipe. In general, this area measured perpendicular to the face plate, is to be not less than 60 per cent of the full cross-sectional area of the face plate, *see Figure 3.1.5 Bracket toe construction*.

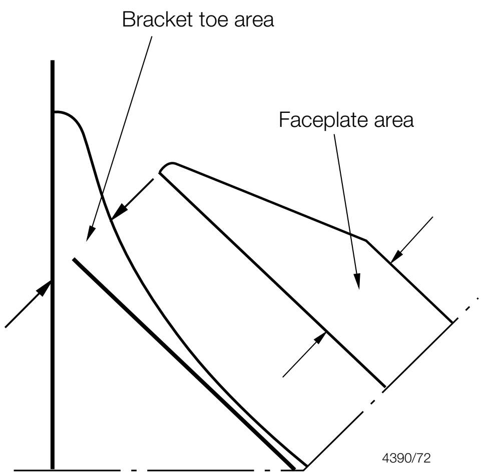


Figure 3.1.5 Bracket toe construction

1.27 Arrangement with offset stiffener

1.27.1 Where the stiffeners of the double bottom floors and transverse bulkheads are unconnected to the secondary members and offset from them, *see Figure 3.1.6 Arrangement with offset stiffener*, the collar arrangement for the secondary members are to satisfy the requirements of *Pt 7, Ch 3, 1.28 Arrangements at intersection of continuous secondary and primary members*. In addition, the fillet welds attaching the lugs to the secondary members are to be based on a weld factor of 0,44 for the throat thickness. To facilitate access for welding the offset stiffeners are to be located 50 mm from the slot edge furthest from the web of the secondary member. The ends of the offset stiffeners are to be suitably tapered and softened.

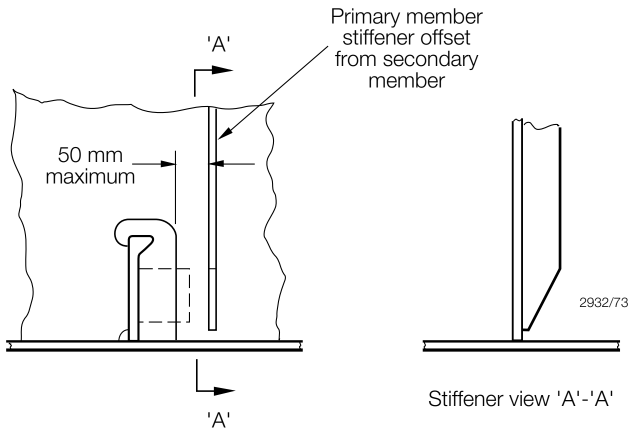


Figure 3.1.6 Arrangement with offset stiffener

1.27.2 Alternative arrangements will be considered on the basis of their ability to transmit load with equivalent effectiveness. Details of the calculations made and testing procedures are to be submitted.

1.28 Arrangements at intersection of continuous secondary and primary members

1.28.1 Cut-outs for the passage of secondary members through the webs of primary members, and the related collaring arrangements, are to be designed to minimise stress concentrations around the perimeter of the opening and in the attached hull envelope or bulkhead plating. The critical shear buckling stress of the panel in which the cut-out is made is to be investigated. Cut-outs for longitudinals will be required to have double lugs in areas of high stress.

1.28.2 The cross-sectional areas of connections are to be determined from the load transmitted through each component in association with its appropriate permissible stress.

1.28.3 The load transmitted through the intersection arrangement is to be determined using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft respectively.

1.28.4 Total load, *P*, transmitted to the primary member from the secondary member is to be derived by:

$$P = \frac{s}{1000}\left(S - \frac{s}{2000}\right)p \quad \text{in kN}$$

where

s = secondary stiffener spacing, mm

S = primary stiffener spacing, m

p = design plating pressure, kN/m^2

P = total load, kN

1.28.5 The arrangement of lug/collar/direct connection to the primary web stiffener determines the load apportioned to each component. The effect on each component of the intersection is to be assessed, as appropriate, for shear and direct stress. Where the web stiffener is not connected to the secondary member, the load, *P*, is transmitted through the lug/collar/direct connection.

1.28.6 The breadth of cut-outs is to be as small as practicable, with the top edge suitably radiused. Cut-outs are to have smooth edges, and the corner radii are to be as large as practicable. Where the web depth is greater than 100 mm the corner radii are to be a minimum of 20 per cent of the breadth of the cut-out or 20 mm, whichever is the greater, and for large cut-outs greater than 250 mm deep, the web plate connection to the hull envelope, or bulkhead, should end in a smooth tapered `soft toe'. Recommended shapes of cut-out are shown in *Figure 3.1.7 Cut-outs and connections*, but consideration will be given to other shapes on the basis of maintaining equivalent strength and minimising stress concentration, *see also* LR's *Guidance Notes for Structural Details*.

1.28.7 Consideration is to be given to the provision of adequate drainage and unimpeded flow of air and water when designing the cut-outs and connection details.

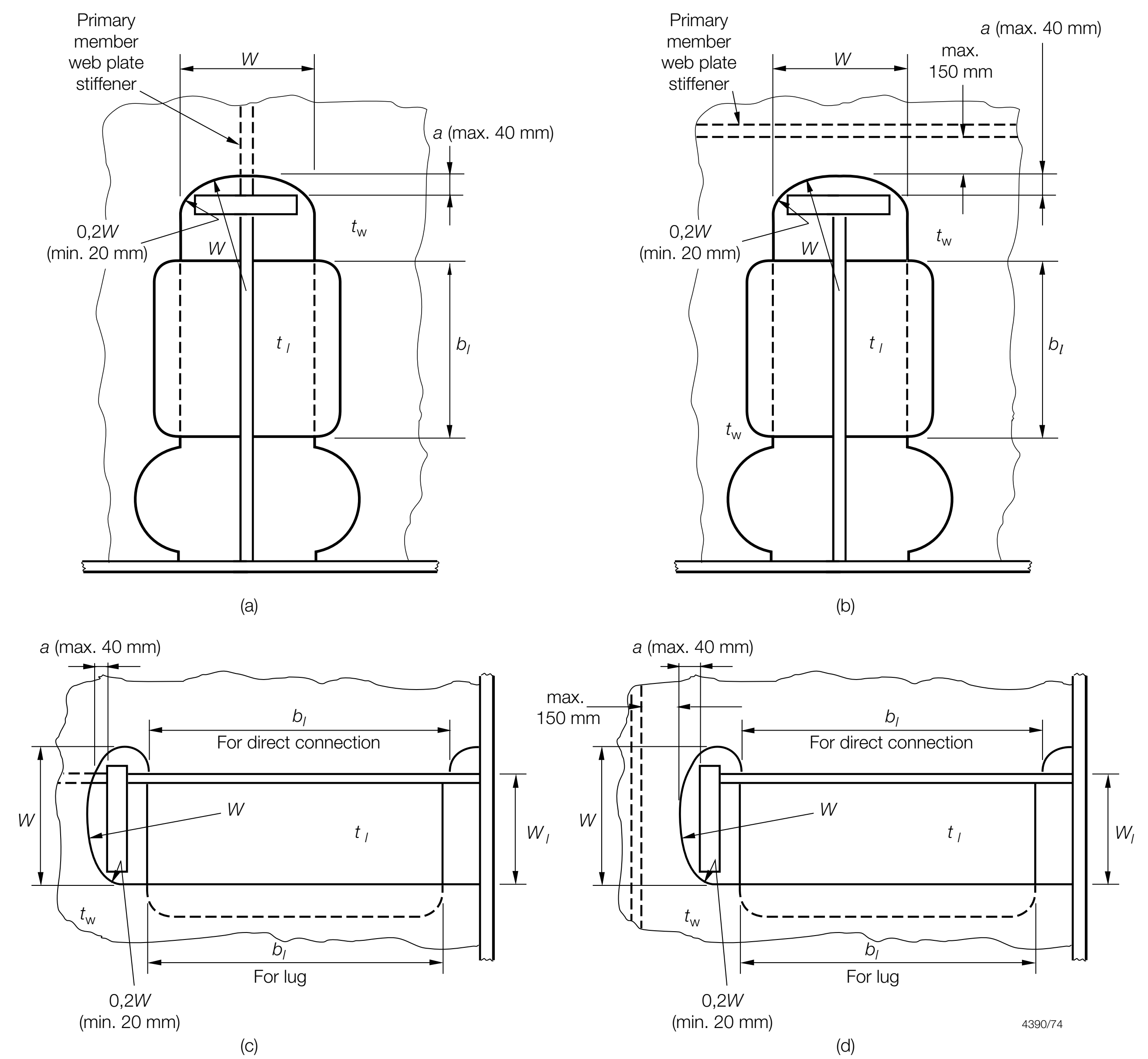


Figure 3.1.7 Cut-outs and connections

1.28.8 Asymmetrical secondary members are to be connected on the heel side to the primary member web plate. Additional connection by lugs on the opposite side may be required.

1.28.9 Symmetrical secondary members are to be connected by lugs on one or both sides, as necessary.

1.28.10 Where the primary member stiffener is connected to the secondary member it is to be aligned with the web of the secondary member, except where the face plate of the latter is offset and abutted to the web, in which case the stiffener connection is to be lapped.

1.28.11 Fabricated longitudinals having the face plate welded to the underside of the web, leaving the edge of the web exposed, are not recommended for side shell and longitudinal bulkhead longitudinals. Where it is proposed to fit such sections, a symmetrical arrangement of connection to transverse members is to be incorporated. This can be achieved by fitting backing structure on the opposite side of the transverse web or bulkhead.

1.28.12 Where a bracket is fitted to the primary member web plate in addition to a connected stiffener it is to be arranged on the opposite side to, and in alignment with the stiffener. The arm length of the bracket is to be not less than the depth of the stiffener, and its cross-sectional area through the throat of the bracket is to be included in the calculation of the area of the primary web stiffener in way of the connection.

1.28.13 Alternative arrangements will be considered on the basis of their ability to transmit load with equivalent effectiveness. Details of the calculations made and testing procedures are to be submitted.

1.29 Openings

1.29.1 Manholes, lightening holes and other cut-outs are to be avoided in way of concentrated loads and areas of high shear. In particular, manholes and similar openings are not to be cut in vertical or horizontal diaphragm plates in narrow cofferdams or in floors and double bottom girders close to their span ends, or below the heels of pillars, unless the stresses in the plating and the panel buckling characteristics have been calculated and found satisfactory.

1.29.2 Manholes, lightening holes and other openings are to be suitably framed and stiffened where necessary.

1.29.3 Air and drain holes, notches and scallops are to be kept at least 200 mm clear of the toes of end brackets and other areas of high stress. Openings are to be well rounded with smooth edges. Closely spaced scallops are not permitted. Widely spaced air or drain holes may be accepted, provided that they are of elliptical shape, or equivalent, to minimise stress concentration and are, in general, cut clear of the weld connection.

1.30 Fittings and attachments, general

1.30.1 The quality of welding and general workmanship of fittings and attachments as given in *Pt 7, Ch 3, 1.31 Bilge keels and ground bars* and *Pt 7, Ch 3, 1.32 Other fittings and attachments* are to be in accordance with *Pt 7, Ch 2, 3.7 Acceptance criteria*.

1.31 Bilge keels and ground bars

1.31.1 It is recommended that bilge keels are not to be fitted in the forward $0{,}3L_R$ region on ships intended to navigate in ice conditions.

1.31.2 Bilge keels are to be attached to a continuous ground bar as shown in *Figure 3.1.8 Bilge keel construction*. Butt welds in shell plating, ground bar and bilge keels are to be staggered.

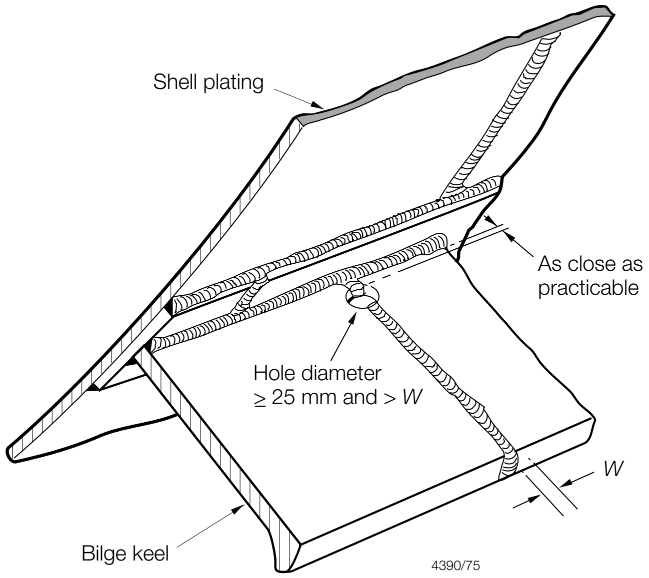


Figure 3.1.8 Bilge keel construction

1.31.3 The thickness of the ground bar is to be not less than the thickness of the bottom shell or 8 mm, whichever is the greater, but need not be taken as greater than 15 mm.

1.31.4 The material class, grade and quality of the ground bar are to be similar to those of the adjacent shell plating.

1.31.5 The ground bar is to be connected to the shell with a continuous fillet weld and the bilge keel to the ground bar with a light continuous fillet weld.

1.31.6 Direct connection between ground bar butt welds and shell plating, and between bilge keel butt welds and ground bar is to be avoided.

1.31.7 The end details of bilge keels and intermittent bilge keels, where adopted, are to be as shown in *Figure 3.1.9 Bilge keel end design*.

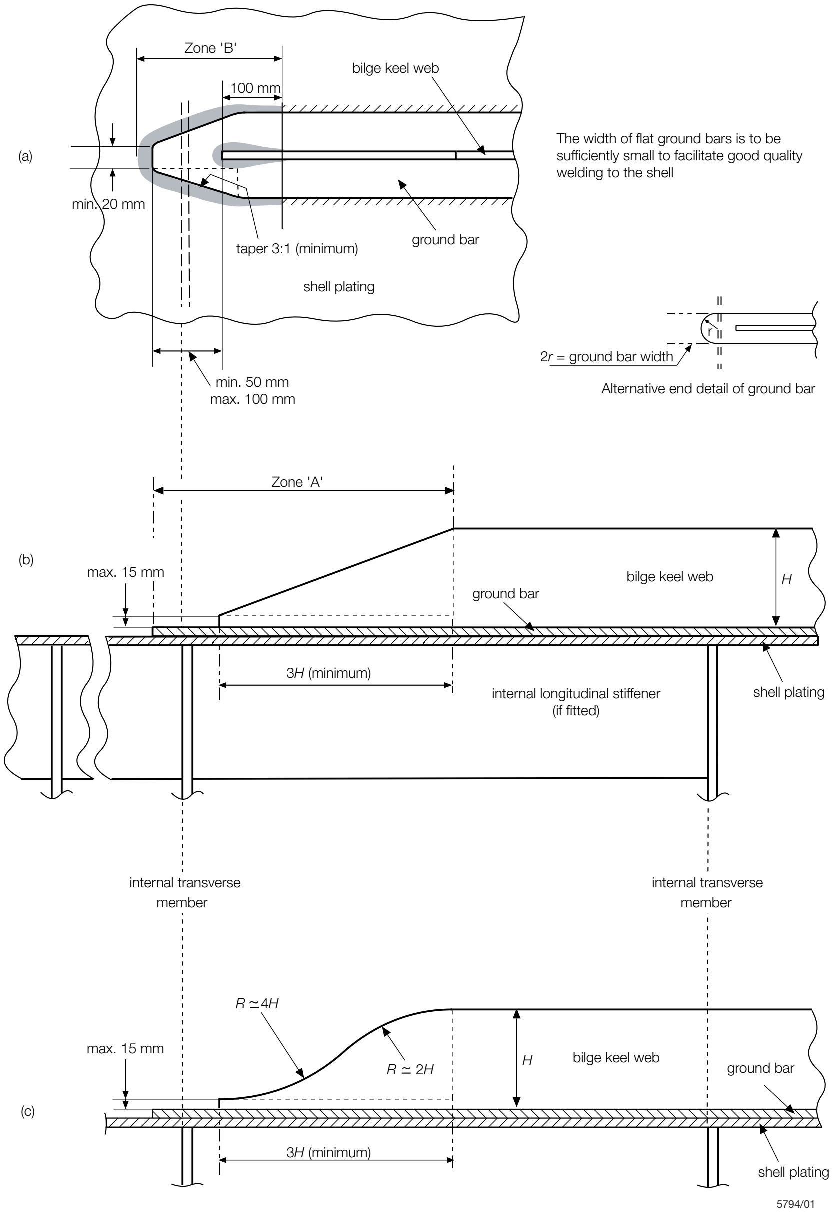


Figure 3.1.9 Bilge keel end design

1.31.8 The ground bar and bilge keel ends are to be tapered or rounded. Where the ends are tapered, the tapers are to be gradual with ratios of at least 3:1, *see Figure 3.1.9 Bilge keel end design*(a) and (b). Where the ends are rounded, details are to be as shown in *Figure 3.1.9 Bilge keel end design*(c). Cut-outs on the bilge keel web within zone 'A' (*see Figure 3.1.9 Bilge keel end design*(b)) are not permitted.

1.31.9 The end of the bilge keel web is to be between 50 mm and 100 mm from the end of the ground bar, *see Figure 3.1.9 Bilge keel end design*(a).

1.31.10 An internal transverse support is to be positioned as close as possible to halfway between the end of the bilge keel web and the end of the ground bar, *see Figure 3.1.9 Bilge keel end design*(b).

1.31.11 Where an internal longitudinal stiffener is fitted in line with the bilge keel web, the longitudinal stiffener is to extend to at least the nearest transverse member outside zone 'A', *see Figure 3.1.9 Bilge keel end design*(b). In this case, the requirement of *Pt 7, Ch 3, 1.31 Bilge keels and ground bars 1.31.10* does not apply.

1.31.12 For craft over 65 m in length, L_R, holes are to be drilled in the bilge keel butt welds. The size and position of these holes are to be as illustrated in *Figure 3.1.8 Bilge keel construction*. Where the butt weld has been subject to non-destructive examination the stop hole may be omitted.

1.31.13 Bilge keels of a different design from that shown in *Figure 3.1.8 Bilge keel construction* and *Figure 3.1.9 Bilge keel end design* will be specially considered.

1.31.14 Within zone 'B' (*see Figure 3.1.9 Bilge keel end design*(a)), welds at the ends of the ground bar and the bilge plating, and at the ends of the bilge keel web and ground bar, are to have weld factors of 0,44 and 0,34 respectively. These welds are to be ground and to blend smoothly with the base materials.

1.31.15 A plan of the bilge keels is to be submitted for approval of material grades, welded connections and detail design.

1.32 Other fittings and attachments

1.32.1 Gutterway bars at the upper deck are to be so arranged that the effect of main hull stresses on them is minimised.

1.32.2 Minor attachments, such as pipe clips, staging lugs and supports, are generally to be kept clear of toes of end brackets, corners of openings and similar areas of high stress. Where connected to asymmetrical stiffeners, the attachments may be in line with the web providing the fillet weld leg length is clear of the offset face plate or flange edge. Where this cannot be achieved the attachments are to be connected to the web, and in the case of flanged stiffeners they are to be kept at least 25 mm clear of the flange edge. On symmetrical stiffeners, they may be connected to the web or to the centreline of the face plate in line with the web.

1.32.3 Where necessary in the construction of the craft, lifting lugs may be welded to the hull plating but they are not to be slotted through. Where they are subsequently removed, this is to be carried out by mechanical cutting close to the plate surface, and the remaining material and welding ground off. After removal the area is to be carefully examined to ensure freedom from cracks or other defects in the plate surface.

■ *Section 2*
Minimum thickness requirements

2.1 General

2.1.1 The thickness of plating and stiffeners determined from the Rule scantling requirements is in no case to be less than that given in *Table 3.2.1 Minimum thickness requirements* for the craft type.

2.1.2 In addition, where plating contributes to the global strength of the craft, the thickness is to be not less than that required to satisfy the global strength requirements detailed in *Pt 7, Ch 6 Hull Girder Strength*.

2.2 Corrosion margin

2.2.1 The minimum thicknesses given in *Table 3.2.1 Minimum thickness requirements* are based on the assumption that there is negligible loss in strength by corrosion. Where this is not the case the minimum thickness will be specially considered.

Table 3.2.1 Minimum thickness requirements

Item	Minimum thickness (mm)		
	Mono-hull	Hydrofoil	Rigid inflatable boat (RIB)
Shell envelope			
Bottom shell plating	$\omega\sqrt{k_{\mathrm{m}}}\left(0,7\sqrt{L_{\mathrm{R}}}+1,0\right)\geq 4,0\,\omega$	$\omega\sqrt{k_{\mathrm{m}}}\left(0,7\sqrt{L_{\mathrm{R}}}+1,0\right)\geq 4,0\,\omega$	$\omega\sqrt{k_{\mathrm{m}}}\left(0,7\sqrt{L_{\mathrm{R}}}+1,0\right)\geq 4,0\,\omega$
Side shell plating	$\omega\sqrt{k_{\mathrm{m}}}\left(0,5\sqrt{L_{\mathrm{R}}}+1,4\right)\geq 3,5\,\omega$	$\omega\sqrt{k_{\mathrm{m}}}\left(0,5\sqrt{L_{\mathrm{R}}}+1,4\right)\geq 3,5\,\omega$	$\omega\sqrt{k_{\mathrm{m}}}\left(0,5\sqrt{L_{\mathrm{R}}}+1,4\right)\geq 3,5\,\omega$
Single bottom structure			

Centre girder web	$\omega\sqrt{k_{\mathrm{m}}}\left(1,1\sqrt{L_{\mathrm{R}}}+1,4\right)\geq 5,0\,\omega$	$\omega\sqrt{k_{\mathrm{m}}}\left(1,1\sqrt{L_{\mathrm{R}}}+1,4\right)\geq 5,0\,\omega$	$\omega\sqrt{k_{\mathrm{m}}}\left(1,1\sqrt{L_{\mathrm{R}}}+1,4\right)\geq 5,0\,\omega$
Floor webs	$\omega\sqrt{k_{\mathrm{m}}}\left(0,8\sqrt{L_{\mathrm{R}}}+1,1\right)\geq 4,0\,\omega$	$\omega\sqrt{k_{\mathrm{m}}}\left(0,8\sqrt{L_{\mathrm{R}}}+1,1\right)\geq 4,0\,\omega$	$\omega\sqrt{k_{\mathrm{m}}}\left(0,8\sqrt{L_{\mathrm{R}}}+1,1\right)\geq 4,0\,\omega$
Side girder webs	$\omega\sqrt{k_{\mathrm{m}}}\left(0,8\sqrt{L_{\mathrm{R}}}+1,1\right)\geq 4,0\,\omega$	$\omega\sqrt{k_{\mathrm{m}}}\left(0,8\sqrt{L_{\mathrm{R}}}+1,1\right)\geq 4,0\,\omega$	$\omega\sqrt{k_{\mathrm{m}}}\left(0,8\sqrt{L_{\mathrm{R}}}+1,1\right)\geq 4,0\,\omega$
Double bottom structure Centre girder			
(1)Within 0,4L_{R} amidships	$\omega\sqrt{k_{\mathrm{m}}}\left(1,1\sqrt{L_{\mathrm{R}}}+1,4\right)\geq 5,0\,\omega$	$\omega\sqrt{k_{\mathrm{m}}}\left(1,1\sqrt{L_{\mathrm{R}}}+1,4\right)\geq 5,0\,\omega$	$\omega\sqrt{k_{\mathrm{m}}}\left(1,1\sqrt{L_{\mathrm{R}}}+1,4\right)\geq 5,0\,\omega$
(2) Outside 0,4L_{R} amidships	$\omega\sqrt{k_{\mathrm{m}}}\left(0,95\sqrt{L_{\mathrm{R}}}+1,4\right)\geq 5,0\,\omega$	$\omega\sqrt{k_{\mathrm{m}}}\left(0,95\sqrt{L_{\mathrm{R}}}+1,4\right)\geq 5,0\,\omega$	$\omega\sqrt{k_{\mathrm{m}}}\left(0,95\sqrt{L_{\mathrm{R}}}+1,4\right)\geq 5,0\,\omega$
Floors and side girders	$\omega\sqrt{k_{\mathrm{m}}}\left(0,8\sqrt{L_{\mathrm{R}}}+1,1\right)\geq 4,0\,\omega$	$\omega\sqrt{k_{\mathrm{m}}}\left(0,8\sqrt{L_{\mathrm{R}}}+1,1\right)\geq 4,0\,\omega$	$\omega\sqrt{k_{\mathrm{m}}}\left(0,8\sqrt{L_{\mathrm{R}}}+1,1\right)\geq 4,0\,\omega$
Inner bottom plating	$\omega\sqrt{k_{\mathrm{m}}}\left(0,7\sqrt{L_{\mathrm{R}}}+1,3\right)\geq 3,5\,\omega$	$\omega\sqrt{k_{\mathrm{m}}}\left(0,7\sqrt{L_{\mathrm{R}}}+1,3\right)\geq 3,5\,\omega$	$\omega\sqrt{k_{\mathrm{m}}}\left(0,7\sqrt{L_{\mathrm{R}}}+1,3\right)\geq 3,5\,\omega$
Bulkheads Watertight bulkhead plating	$\omega\sqrt{k_{\mathrm{m}}}\left(0,43\sqrt{L_{\mathrm{R}}}+1,2\right)\geq 3,0\,\omega$	$\omega\sqrt{k_{\mathrm{m}}}\left(0,43\sqrt{L_{\mathrm{R}}}+1,2\right)\geq 3,0\,\omega$	$\omega\sqrt{k_{\mathrm{m}}}\left(0,43\sqrt{L_{\mathrm{R}}}+3,0\right)\geq 3,0\,\omega$
Deep tank bulkhead plating	$\omega\sqrt{k_{\mathrm{m}}}\left(0,5\sqrt{L_{\mathrm{R}}}+1,4\right)\geq 3,5$	$\omega\sqrt{k_{\mathrm{m}}}\left(0,5\sqrt{L_{\mathrm{R}}}+1,4\right)\geq 3,5\,\omega$	$\omega\sqrt{k_{\mathrm{m}}}\left(0,5\sqrt{L_{\mathrm{R}}}+1,4\right)\geq 3,5\,\omega$
Deck plating and stiffeners Strength/Main deck plating	$\omega\sqrt{k_{\mathrm{m}}}\left(0,5\sqrt{L_{\mathrm{R}}}+1,4\right)\geq 3,5\,\omega$	$\omega\sqrt{k_{\mathrm{m}}}\left(0,5\sqrt{L_{\mathrm{R}}}+1,4\right)\geq 3,5\,\omega$	$\omega\sqrt{k_{\mathrm{m}}}\left(0,5\sqrt{L_{\mathrm{R}}}+1,4\right)\geq 3,5\,\omega$
Lower deck/Inside deckhouse	$\omega\sqrt{k_{\mathrm{m}}}\left(0,3\sqrt{L_{\mathrm{R}}}+1,3\right)\geq 3,0\,\omega$	$\omega\sqrt{k_{\mathrm{m}}}\left(0,3\sqrt{L_{\mathrm{R}}}+1,3\right)\geq 3,0\,\omega$	$\omega\sqrt{k_{\mathrm{m}}}\left(0,3\sqrt{L_{\mathrm{R}}}+1,3\right)\geq 3,0\,\omega$
Superstructures and deckhouses Superstructure side plating	$\omega\sqrt{k_{\mathrm{m}}}\left(0,4\sqrt{L_{\mathrm{R}}}+1,1\right)\geq 3,0\,\omega$	$\omega\sqrt{k_{\mathrm{m}}}\left(0,4\sqrt{L_{\mathrm{R}}}+1,1\right)\geq 3,0\,\omega$	$\omega\sqrt{k_{\mathrm{m}}}\left(0,4\sqrt{L_{\mathrm{R}}}+1,1\right)\geq 3,0\,\omega$
Deckhouse front 1st tier	$\omega\sqrt{k_{\mathrm{m}}}\left(0,62\sqrt{L_{\mathrm{R}}}+1,8\right)\geq 3,5\,\omega$	$\omega\sqrt{k_{\mathrm{m}}}\left(0,62\sqrt{L_{\mathrm{R}}}+1,8\right)\geq 3,5\,\omega$	$\omega\sqrt{k_{\mathrm{m}}}\left(0,62\sqrt{L_{\mathrm{R}}}+1,8\right)\geq 3,5\,\omega$
Deckhouse front upper tiers	$\omega\sqrt{k_{\mathrm{m}}}\left(0,55\sqrt{L_{\mathrm{R}}}+1,5\right)\geq 3,0\,\omega$	$\omega\sqrt{k_{\mathrm{m}}}\left(0,55\sqrt{L_{\mathrm{R}}}+1,5\right)\geq 3,0\,\omega$	$\omega\sqrt{k_{\mathrm{m}}}\left(0,55\sqrt{L_{\mathrm{R}}}+1,5\right)\geq 3,0\,\omega$
Deckhouse aft	$\omega\sqrt{k_{\mathrm{m}}}\left(0,25\sqrt{L_{\mathrm{R}}}+0,7\right)\geq 2,5\,\omega$	$\omega\sqrt{k_{\mathrm{m}}}\left(0,25\sqrt{L_{\mathrm{R}}}+0,7\right)\geq 2,5\,\omega$	$\omega\sqrt{k_{\mathrm{m}}}\left(0,25\sqrt{L_{\mathrm{R}}}+0,7\right)\geq 2,5\,\omega$
Pillars Wall thickness of tubular pillars	$\omega\sqrt{k_{\mathrm{m}}}0,07d_{\mathrm{p}}$	$\omega\sqrt{k_{\mathrm{m}}}0,07d_{\mathrm{p}}$	$\omega\sqrt{k_{\mathrm{m}}}0,07d_{\mathrm{p}}$
Wall thickness of rectangular pillars	$\omega\sqrt{k_{\mathrm{m}}}0,07b_{\mathrm{p}}$	$\omega\sqrt{k_{\mathrm{m}}}0,07b_{\mathrm{p}}$	$\omega\sqrt{k_{\mathrm{m}}}0,07b_{\mathrm{p}}$
Symbols			

ω	=	= service type correction factor as determined from *Table 3.2.2 Service type correction factors (ω)*
k_m	=	= $385/(\sigma_A + \sigma_u)$
σ_A	=	= specified minimum yield stress or 0,2% proof stress of the alloy in unwelded condition, in N/mm^2
σ_u	=	= specified minimum ultimate tensile strength of the alloy in unwelded condition, in N/mm^2
b_p	=	= minimum breadth of cross section of hollow rectangular pillar, in mm
d_p	=	= outside diameter of tubular pillar, in mm

L_R is as defined in *Pt 7, Ch 3, 1.5 Symbols and definitions 1.5.1*

2.3 Impact considerations

2.3.1 Due consideration is to be given to the scantlings of all structure which may be subject to local impact loadings. Impact testing may be required to be carried out at the discretion of LR to demonstrate the suitability of the proposed scantlings for a particular application.

2.4 Sheathing

2.4.1 Areas of shell and deck which are subject to additional wear by abrasion e.g. passenger routes, working areas of fishing craft, forefoot region etc, are to suitably protected by local reinforcement or sheathing. This sheathing may be of timber, rubber, steel, additional layers of reinforcement, etc. as appropriate. Details of such sheathing and the method of attachment are to be submitted for consideration.

2.4.2 The attachment of sheathing by mechanical means such as bolting or other methods is not to impair the watertight integrity of the craft. Through bolting of the hull is to be kept to a minimum and avoided where practicable. The design arrangements in way of any through bolting are to be such that damage to the sheathing will not impair the watertight integrity of the hull.

2.5 Operation in ice

2.5.1 The minimum plating thickness of craft intended for operation in ice conditions is to comply with *Pt 7, Ch 5, 7 Strengthening requirements for navigation in ice conditions*.

Table 3.2.2 Service type correction factors (ω)

Service type notation	ω
Cargo	1,1
Passenger	1,0
Patrol	1,0
Pilot	1,1
Yacht	1,0
Workboat MFV	1,2

■ *Section 3*
Shell envelope plating

3.1 General

3.1.1 The requirements of this Section are applicable to longitudinally and transversely framed shell envelopes.

3.1.2 The thickness of the shell envelope plating is in no case to be less than the appropriate minimum requirement given in *Pt 7, Ch 3, 2 Minimum thickness requirements*.

3.2 Plate keel

3.2.1 The breadth, b_k, and thickness, t_k, of the plate keel are not to be taken as less than:

$$b_{\mathrm{k}} = 7,0 L_{\mathrm{R}} + 340 \text{ mm}$$

$$t_{\mathrm{k}} = 1,85 \sqrt{k_{\mathrm{a}}} L^{\ 0,45}_{\ \mathrm{R}} \text{ mm}$$

where L_R and k_a are as defined in *Pt 7, Ch 3, 1.5 Symbols and definitions 1.5.1*.

3.2.2 In no case is the thickness of the plate keel to be less than that of the adjacent bottom shell plating.

3.2.3 The width and thickness of the plate keel are to be maintained throughout the length of the craft from the transom to a point not less than 25 per cent of the freeboard (measured at the forward perpendicular) above the deepest load waterline on the stem. Thereafter the keel thickness may be reduced to that required by *Pt 7, Ch 3, 3.3 Plate stem 3.3.1* for the stem.

3.2.4 For large or novel craft and for yachts with externally attached ballast keels, the scantlings of the keel will be specially considered.

3.2.5 For bar keels, *see Pt 7, Ch 3, 5.2 Keel 5.2.2*.

3.3 Plate stem

3.3.1 The thickness of plate stems, t_s, is not to be taken as less than:

$$t_{\mathrm{s}} = \sqrt{k_{\mathrm{a}}} \left(0,14 L_{\mathrm{R}} + 4 \right) \text{ mm}$$

L_R and k_a are as defined in *Pt 7, Ch 3, 1.5 Symbols and definitions 1.5.1*.

3.3.2 In no case is the thickness of the plate stem to be taken as less than the thickness of the adjacent shell plating.

3.3.3 Plate stems are to be supported by horizontal diaphragms, and where the stem radius is large, a centreline stiffener or web may be required. Where this is impracticable due to fabrication access considerations, alternative supporting arrangements will be specially considered.

3.3.4 For large or novel craft the scantlings of the stem will be specially considered.

3.3.5 The breadth of plate stems is to be not less than the width of keel as required by *Pt 7, Ch 3, 3.2 Plate keel 3.2.1*.

3.4 Bottom shell plating

3.4.1 The thickness of the bottom shell plating is to be determined from the general plating equation given in *Pt 7, Ch 3, 1.16 Plating general* using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

3.4.2 For all craft types the minimum thickness requirement for bottom shell plating, as detailed in *Pt 7, Ch 3, 2 Minimum thickness requirements*, is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater. *See Figure 3.3.1 Extent of bottom shell*.

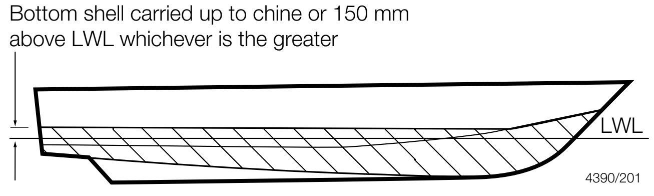


Figure 3.3.1 Extent of bottom shell

3.5 Side shell plating

3.5.1 The thickness of the side shell plating is to be determined from the general plating equation given in *Pt 7, Ch 3, 1.16 Plating general* using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

3.6 Sheerstrake

3.6.1 The sheerstrake is generally to be taken as the side shell, locally reinforced in way of deck/hull connection and fender attachment. The amount of local reinforcement will be dependent upon the arrangement of structure and the proposed service.

3.6.2 The fendering arrangements for all craft types are the responsibility of the designers/Builders and are outside the scope of classification.

3.6.3 Where the pressure or impact loadings that a particular type of craft will experience in service are considered by the Builder, or subsequent Owner, to be not covered by or be greater than those indicated in *Pt 5 Design and Load Criteria* of the Rules, details of the loadings together with the calculations of how these will be satisfactorily distributed into the craft's structure, are to be submitted for consideration with the relevant contruction plans.

3.6.4 The arrangements indicated in *Pt 7, Ch 3, 3.6 Sheerstrake 3.6.5*, *Pt 7, Ch 3, 3.6 Sheerstrake 3.6.6*, *Pt 7, Ch 3, 4.18 Structure in way of fenders 4.18.2* and *Pt 7, Ch 3, 4.18 Structure in way of fenders 4.18.3* for pilot and fishing craft are for the guidance of the Builder and subsequent Owners/operators of the craft. Where the intended service for either of these types of craft, or other types of craft which may be subject to loadings resulting from contact with other craft, jetties or similar loading or boarding facilities, is such that the loadings are greater than those that can be satisfactorily distributed into the craft's structure by the arrangements indicated, then the strengthening arrangements are to be increased accordingly.

3.6.5 For pilot craft which may be subject to repeated impact loadings from contact with other craft etc. the sheerstrake plating is to be increased locally by not less than 50 per cent of the side shell thickness. The increased thickness is to extend from the bow aft over a distance of $0{,}33L_{\text{R}}$ or 500 mm aft of the point which the deckline reaches its greatest breadth whichever is the greater and forward of the quarter and over the transom for a distance of $0{,}075L_{\text{R}}$ or 1,0 m, whichever is the greater. It is in general to extend from the deck edge to below the first longitudinal stiffener, or a vertical distance equivalent to 1/3 the freeboard height whichever is the greater. The additional thickness is then to be tapered out to the side shell thickness in accordance with the Rules.

3.6.6 Fishing craft are in general to have their shell plating scantling as required to satisfy the Rule loadings, increased by 20 per cent. Additionally the side shell is not to be taken less than as bottom shell thickness, and where there are gallows, gantries, nets, or lines etc. the plating in way is to be further increased locally and/or suitably protected by sheathing or other means.

3.6.7 Individual consideration will be given to lesser scantlings than those required by *Pt 7, Ch 3, 3.6 Sheerstrake 3.6.3*. for fishing craft used for pleasure, light duties, etc. Details of the service are to be submitted.

3.6.8 Where a rounded sheerstrake is adopted the radius, in general, is to be not less than 15 times the thickness.

3.6.9 The sheerstrake thickness is to be increased by 20 per cent at the ends of a bridge superstructure extending out to the craft's side. In the case of a bridge superstructure exceeding $0{,}15L_{\text{R}}$, the side plating at the ends of the superstructure is also to be increased by 25 per cent and tapered gradually into the upper deck sheerstrake.

3.6.10 In general, compensation will not be required for openings in the sheerstrake which are clear of the gunwale or deck openings and whose depth does not exceed 20 per cent of the depth of the sheerstrake. Openings are not to be cut in a rounded gunwale.

3.7 Chines

3.7.1 The chine plate thickness is to be equivalent to the bottom shell thickness required to satisfy the Rule pressure loading, increased by 20 per cent, or 6 mm, whichever is the greater.

3.7.2 Where tube is used in chine construction, the minimum wall thickness is to be not less than the thickness of the bottom shell plating increased by 20 per cent.

3.7.3 Full penetration welding of shell plating in way of chines is always to be maintained.

3.7.4 Chine details are to be such that the continuity of structural strength across the panel is maintained. Details of chines are to be submitted for consideration. *See also* LR's *Guidance Notes for Structural Details*.

3.8 Skegs

3.8.1 The thickness of the skeg plating is to be not less than the thickness of the adjacent bottom shell and additionally is to satisfy the requirements for sole pieces given in *Ch 3, 3 Higher strength steels for ship and other structural applications*of the Rules for Materials.

3.9 Transom

3.9.1 The thickness of the stern or transom is to be not less than that required for the side or bottom shell as appropriate. Where water jet or sterndrive units are fitted, the scantlings of the plating in way of the nozzles and connections will be specially considered.

3.10 Fin and tuck

3.10.1 The thickness of the plating is to be increased locally in way of the fin and tuck areas of yachts which have either internal fixed ballast or external attached ballast keels.

3.10.2 The plating thickness is to be not less than 1,25 times the thickness of the adjacent shell plating but need not be greater than the plate keel thickness as required by *Pt 7, Ch 3, 3.2 Plate keel*.

3.11 Shell openings

3.11.1 Sea-inlets, or other openings, are to have well rounded corners and, so far as is practicable, are to be kept clear of the bilge radius, chine or radiused sheerstrake. Arrangements are to be made to maintain the strength in way of the openings.

3.11.2 Openings on or near the bilge radius may be accepted provided that they are of elliptical shape, or equivalent, to minimise stress concentrations and are, in general, to be cut clear of weld connections.

3.12 Sea inlet boxes

3.12.1 The thickness of the sea inlet box plating is to be 1 mm thicker than the adjacent shell plating, or 8 mm, whichever is the greater.

3.13 Local reinforcement/insert plates

3.13.1 The thickness of the shell envelope plating determined in accordance with *Pt 7, Ch 3, 3.4 Bottom shell plating* and *Pt 7, Ch 3, 3.5 Side shell plating* is to be increased locally, by generally not less than 50 per cent in way of sternframe, propeller brackets, rudder horn, stabilisers, hawse pipes and anchor recess. Details of such reinforcement are to be submitted for approval.

3.13.2 Insert plates are to extend outside the line of adjacent supporting structure and then be tapered over a distance of not less than three times the difference in thickness, *see also Pt 7, Ch 2, 4.20 Construction tolerances*.

3.14 Appendages

3.14.1 The scantlings of appendages will be subject to special consideration on the basis of the Rules and the design loadings anticipated, but in no case are to be taken as less than that of the surrounding structure.

3.15 Fender attachment

3.15.1 Wood belting and fenders are to be bolted to lugs welded to a ground bar attached to the shell and not through-bolted to the shell plating.

3.16 Novel features

3.16.1 Where the Rules do not specifically define the requirements for novel features then the scantlings and arrangements are to be determined by direct calculation. Such calculations are to be carried out on the basis of the Rules or recognised standards. Details are to be submitted for consideration.

Section 4
Shell envelope framing

4.1 General

4.1.1 The requirements in this Section apply to longitudinally and transversely framed shell envelopes.

4.1.2 For each stiffening member an assumed load model is stated. Where the proposed stiffener arrangement differs from that assumed, consideration will be given to an alternative load model.

4.1.3 The geometric properties of stiffener sections are to be in accordance with *Pt 7, Ch 3, 1.18 Geometric properties and proportions of stiffener sections*.

4.2 Bottom longitudinal stiffeners

4.2.1 Bottom longitudinal stiffeners are to be supported by bottom transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.2.2 Bottom longitudinals are to be continuous through the supporting structures.

4.2.3 Where it is impracticable to comply with the requirements of *Pt 7, Ch 3, 4.2 Bottom longitudinal stiffeners 4.2.2*, or where it is proposed to terminate the bottom longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets.

4.2.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 7, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (b).

4.3 Bottom longitudinal primary stiffeners

4.3.1 Bottom longitudinal primary stiffeners are to be supported by bottom deep transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 6 m apart.

4.3.2 Bottom longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

4.3.3 Where it is impracticable to comply with the requirements of *Pt 7, Ch 3, 4.3 Bottom longitudinal primary stiffeners 4.3.2*, or where it is proposed to terminate the stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be `soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.3.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 7, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (a).

4.4 Bottom transverse stiffeners

4.4.1 Bottom transverse stiffeners are defined as local stiffening members which support the bottom shell, and which may be continuous or intercostal.

4.4.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 7, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (b).

4.5 Bottom transverse frames

4.5.1 Bottom transverse frames are defined as stiffening members which support the bottom shell. They are to be effectively continuous and bracketed at their end connections to side frames and bottom floors as appropriate.

4.5.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 7, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (a).

4.6 Bottom transverse web frames

4.6.1 Bottom transverse web frames are defined as primary stiffening members which support bottom shell longitudinals. They are to be continuous and substantially bracketed at their end connections to side web frames and bottom floors.

4.6.2 Where it is impracticable to comply with the requirements of *Pt 7, Ch 3, 4.6 Bottom transverse web frames 4.6.1*, or where it is proposed to terminate the bottom transverse web frames in way of longitudinal primary girders bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be `soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.6.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 7, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (a).

4.7 Side longitudinal stiffeners

4.7.1 The side longitudinal stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.7.2 Side longitudinals are to be continuous through the supporting structures.

4.7.3 Where it is impracticable to comply with the requirements of *Pt 7, Ch 3, 4.7 Side longitudinal stiffeners 4.7.2*, or where it is proposed to terminate the side longitudinal in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.7.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 7, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (b).

4.8 Side longitudinal primary stiffeners

4.8.1 Side longitudinal primary stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 6 m apart.

4.8.2 Side longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

4.8.3 Where it is impracticable to comply with the requirements of *Pt 7, Ch 3, 4.8 Side longitudinal primary stiffeners 4.8.2*, or where it is proposed to terminate the side longitudinally in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be `soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.8.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 7, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (a).

4.9 Side transverse stiffeners

4.9.1 Side transverse stiffeners are defined as local stiffening members supporting the side shell and may be continuous or intercostal.

4.9.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 7, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures*

for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (b).

4.10 Side transverse frames

4.10.1 Side transverse frames are defined as stiffening members supporting the side shell and spanning continuously between bottom floors/frames and decks. They are to be effectively constrained against rotation at their end connections.

4.10.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 7, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (a).

4.11 Side transverse web frames

4.11.1 Side transverse web frames are defined as primary stiffening members which support side shell longitudinally. They are to be continuous and substantially bracketed at their head and heel connections to deck transverses and bottom web frames respectively.

4.11.2 Where it is impracticable to comply with the requirements of *Pt 7, Ch 3, 4.11 Side transverse web frames 4.11.1*, or where it is proposed to terminate the web frames in way of side longitudinal primary stiffeners bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets. All brackets are to be `soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.11.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 7, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3 Hull envelope design criteria* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (a).

4.12 Grouped frames

4.12.1 For the purposes of satisfying Rule scantling requirements, frames may, subject to agreement by LR, be grouped. The number of frames in any group shall not in general exceed five. The summation of the section moduli and inertia for the group of frames is not to be less than the summation of the Rule requirement for the individual framing members. In addition, in no case is the proposed scantling of an individual framing member within the group to be less than ninety per cent of the Rule value for that member.

4.13 Grillage structures

4.13.1 For complex girder systems, a complete structural analysis using numerical methods may have to be performed to demonstrate that the stress levels are acceptable when subjected to the most severe and realistic combination of loading conditions intended.

4.13.2 General or special purpose computer programs or any other analytical techniques may be used provided that the effects of bending, shear, axial and torsion are properly accounted for and the theory and idealisation used can be justified.

4.13.3 In general, grillages consisting of slender girders may be idealised as frames based on beam theory provided proper account of the variations of geometric properties is taken. For cases where such an assumption is not applicable, finite element analysis or equivalent methods may have to be used.

4.14 Combined framing systems

4.14.1 Where longitudinal and transverse primary stiffeners form grillage structures the scantlings may be derived in accordance with *Pt 7, Ch 3, 4.13 Grillage structures*.

4.15 Floating framing systems

4.15.1 Floating framing systems, where proposed, will be subject to special consideration.

4.16 Frame struts

4.16.1 Where struts are fitted to side shell transverse web frames or longitudinal primary stiffeners to carry axial loads, the strut cross-sectional area is to be derived as for pillars in *Pt 7, Ch 3, 10 Pillars and pillar bulkheads*. If fitted at the stiffener half span point the stiffener section modulus may be taken as half the modulus derived above.

4.16.2 Design of end connections is to be such that the area of the welding is to be not less than the minimum cross-sectional area of the strut derived in *Pt 7, Ch 3, 4.16 Frame struts 4.16.1*. To achieve this full penetration welding may be required. The weld connections between the face flats and webs of the pillar supporting structure are to be welded using double continuous welding of an equivalent area to that derived by *Pt 7, Ch 3, 4.16 Frame struts 4.16.1*

4.17 Arrangements and details

4.17.1 The arrangement of the connection between the stiffener and the bracket is to be such that at no point in the connection are the section modulus and inertia reduced to less than that of the stiffener with associated plating.

4.17.2 The web stability, openings in the web and continuity and alignment are to be in accordance with *Pt 7, Ch 3, 1.24 Web stability*, *Pt 7, Ch 3, 1.25 Openings in the web* and *Pt 7, Ch 3, 1.26 Continuity and alignment* respectively.

4.17.3 Secondary and primary end connections and arrangements at intersection of continuous secondary and primary members are to be in accordance with *Pt 7, Ch 3, 1.20 Secondary member end connections*, *Pt 7, Ch 3, 1.22 Primary member end connections* and *Pt 7, Ch 3, 1.28 Arrangements at intersection of continuous secondary and primary members* respectively.

4.17.4 Stiffeners in slamming areas are to be lugged or bracketed.

4.18 Structure in way of fenders

4.18.1 For **craft**, including pilot craft and fishing craft, which may be subject to repeated impact loadings from contact with other craft whilst in service, due consideration is to be given to increasing the scantlings of stiffening members in way of fenders. Details of anticipated loadings and calculations for the required increased scantlings are to be submitted, *see also Pt 7, Ch 3, 3.6 Sheerstrake 3.6.3* and *Pt 7, Ch 3, 3.6 Sheerstrake 3.6.4*.

4.18.2 **Pilot craft** are to be fitted with large knees in way of the sheerstrake in areas as indicated in *Pt 7, Ch 3, 6 Double bottom structure*. The knees are to be aligned between the transverse frames and the deck beams. In the case of longitudinally framed craft, intermediate knees are to be fitted with a spacing in general not greater than 500 mm. Where such intermediate brackets are fitted they are to terminate on a side longitudinal with a section modulus of, in general, twice that of the Rule longitudinal for the web frame spacing, and a deck longitudinal. The side longitudinal is to be positioned below any fendering to carry the heel of the knee. Consideration will given to the termination of such brackets by use of a `soft-toe' in way of the deck. The thickness of the webs for these knees is to be twice that required by *Pt 7, Ch 3, 1.21 Scantlings of end brackets*.

4.18.3 **Fishing craft** engaged in pair trawling and other modes of fishing, and which may be subject to repeated impact loading from contact with the other craft are to have additional stiffening fitted in way of the impact areas. This may be in the form of large knees, intermediate knees, substantial fendering/ rubbing strakes.

4.19 Novel features

4.19.1 The scantlings are to be determined by direct calculation where the shell framing is of unusual design, form or proportions.

■ *Section 5*
Single bottom structure and appendages

5.1 General

5.1.1 The requirements of this Section provide for single bottom construction in association with transverse and longitudinal framing systems.

5.1.2 All girders are to extend as far forward and aft as practicable and care is to be taken to avoid any abrupt discontinuity. Where girders are cut at bulkheads, their longitudinal strength is to be maintained.

5.1.3 Particular attention is to be taken to ensure that the continuity of structural strength in way of the intersection of transverse floors and longitudinal girders is maintained. The face flats of such stiffening members are to be effectively connected.

5.1.4 The single bottom structure in way of the keel and girders is to be sufficient to withstand the forces imposed by dry-docking the craft.

5.1.5 The scantlings of the single bottom structure are to comply with the appropriate minimum requirements given in *Pt 7, Ch 3, 2 Minimum thickness requirements*.

5.2 Keel

5.2.1 The breadth, and thickness of plate keels are to comply with the requirements of *Pt 7, Ch 3, 3.2 Plate keel*.

5.2.2 The cross-sectional area, A_k, and thickness, t_k, of bar keels are not, in general, be taken as less than:

$$A_k = k_a\left(1,85L_R + 2\right)\ \text{cm}^2$$

$$t_k = \sqrt{k_a}\left(0,7L_R + 8,25\right)\ \text{mm}$$

where L_R and k_a are as defined in *Pt 7, Ch 3, 1.5 Symbols and definitions 1.5.1*

5.3 Centre girder

5.3.1 A centreline girder is, in general, to be fitted throughout the length of the hull in association with transverse frames, transverses supporting longitudinals or where the breadth of floors at the upper edge is greater than 1,5 m.

5.3.2 Centreline girders are to be formed of intercostal or continuous plate webs with a face flat welded to the upper edge. In all cases the face flat is to be continuous. Where girder webs are intercostal, additional bracketing and local reinforcement will be required to maintain the continuity of structural strength.

5.3.3 The web depth of the centre girder is, in general, to be equal to the depth of the floors at the centreline as specified in *Pt 7, Ch 3, 5.5 Floors general 5.5.3*.

5.3.4 The web thickness, t_w, is to be taken not less than:

$$t_w = 1,4\sqrt{k_a}\left(\sqrt{L_R} + 1\right)\ \text{mm}$$

where L_R and k_a are as defined in *Pt 7, Ch 3, 1.5 Symbols and definitions 1.5.1*.

5.3.5 The geometric properties of the centre girder are to be in accordance with *Pt 7, Ch 3, 1.18 Geometric properties and proportions of stiffener sections*.

5.3.6 The face flat area of the centre girder, A_f, is to be not less than:

$$A_f = 0,56L_R k_a\ \text{cm}^2$$

5.3.7 The face flat area of the centre girder outside $0,5L_R$ amidships may be 80 per cent of the value given in *Pt 7, Ch 3, 5.3 Centre girder 5.3.6*.

5.3.8 The face flat thickness is to be not less than the thickness of the web.

5.3.9 The ratio of the width to thickness of the face flat is to be not less than eight but should not exceed 16.

5.3.10 Additionally, the requirements of *Pt 7, Ch 3, 4.3 Bottom longitudinal primary stiffeners* for bottom longitudinal primary stiffeners are to be complied with.

5.4 Side girders

5.4.1 Where the floor breadth at the upper edge exceeds 6,0 m side girders are to be fitted at each side of the centre girder such that the spacing between the side and centre girders or between the side girders themselves is not greater than 3 m. Side girders where fitted are to extend as far forward and aft as practicable and are, in general, to terminate in way of bulkheads, deep floors or other primary transverse structure.

5.4.2 The web thickness of side girders is to be taken as not less than:

$$t_w = 1,4\sqrt{k_a L_R}\ \text{mm}$$

where L_R and k_a are as defined in *Pt 7, Ch 3, 1.5 Symbols and definitions 1.5.1*.

5.4.3 The face flat area and thickness of side girders are to comply with the requirements for plate floors as defined in *Pt 7, Ch 3, 5.5 Floors general 5.5.6* and *Pt 7, Ch 3, 5.5 Floors general 5.5.7*.

5.4.4 Watertight side girders, and side girders forming the boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads and deeptanks as detailed in *Pt 7, Ch 3, 7.3 Watertight bulkhead stiffening* and *Pt 7, Ch 3, 7.5 Deep tank stiffening* respectively.

5.4.5 In the engineroom, additional side girders are generally to be fitted in way of main machinery seatings. Where fitted, they are to be integrated into the structure of the craft and extended forward and aft as far as practicable.

5.4.6 Additionally, the requirements of *Pt 7, Ch 3, 4.3 Bottom longitudinal primary stiffeners* for bottom longitudinal primary stiffeners are to be complied with.

5.5 Floors general

5.5.1 In transversely framed craft, plate floors are generally to be fitted at each frame.

5.5.2 In longitudinally framed craft, plate floors are to be fitted at every transverse web and generally at a spacing not exceeding 2 m. Additional transverse floors or webs are in general to be fitted at half web-frame spacing in way of engine seatings and thrust bearings, pillars, skegs, ballast/bilge keels and the bottom of the craft forward.

5.5.3 The overall depth, d_f, of plate floors at the centreline is not to be taken as less than:

when $B < 10$ m	$d_f = 40(B + 0{,}85D)$ mm
when $B \geq 10$ m	$d_f = 40(1{,}5B + 0{,}85D) - 200$ mm

D is defined in *Pt 3, Ch 1, 6.2 Principal particulars 6.2.8*

5.5.4 The web thickness, t_w, of plate floors, is to be in accordance with *Pt 7, Ch 3, 1.18 Geometric properties and proportions of stiffener sections* and is to be taken as not less than:

$$t_w = \sqrt{k_a}\left(\frac{4,7d_f}{1000} + 3,1\right)\left(\frac{s}{1000} + 0,5\right) \text{ mm}$$

where

d_f is to be determined from *Pt 7, Ch 3, 5.5 Floors general 5.5.3*

k_a and *s* are as defined in *Pt 7, Ch 3, 1.5 Symbols and definitions 1.5.1*.

5.5.5 If the side frames of the craft are attached to the floors by brackets, the depth of floor may be reduced by 15 per cent and the floor thickness determined using the reduced depth. The brackets are to be flanged and have the same thickness as the floors, and their arm lengths clear of the frame are to be the same as the reduced floor depth given above.

5.5.6 The face flat area of floors, A_f, is not to be taken as less than:

$$A_f = 0,28 k_a L_R \text{ cm}^2$$

where

k_a and L_R are defined in *Pt 7, Ch 3, 1.5 Symbols and definitions 1.5.1*.

5.5.7 The face flat thickness is to be not less than the thickness of the web and the ratio of the web to the thickness of the face flat is to be not less than eight but is not to exceed 16.

5.5.8 Additionally the requirements of *Pt 7, Ch 3, 4.6 Bottom transverse web frames* for bottom transverse web frames are to be complied with.

5.5.9 Floors are generally to be continuous from side to side.

5.5.10 The tops of floors, in general, may be level from side to side. However, in craft having considerable rise of floor the depth of the floor plate may require to be increased to maintain the required section modulus.

5.5.11 The floors in the aft peak are to extend over and provide effective support to the sterntube(s) where applicable.

5.5.12 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deeptanks as detailed in *Pt 7, Ch 3, 7.3 Watertight bulkhead stiffening* and *Pt 7, Ch 3, 7.5 Deep tank stiffening*.

5.6 Floors in machinery spaces

5.6.1 The thickness, t_w, of the floors in machinery spaces is to be 1 mm greater than that required by *Pt 7, Ch 3, 5.5 Floors general 5.5.4*.

5.6.2 The depth and section modulus of floors anywhere between engine or gearbox girders is to be not less than that required to maintain continuity of structural integrity or 50 per cent of the depth given in *Pt 7, Ch 3, 5.5 Floors general 5.5.3*. The face flat area and web thickness for such reduced floor heights are to be increased appropriately in order to maintain continuity of structural strength, *see also Pt 7, Ch 3, 4.12 Grouped frames*.

5.7 Machinery seatings

5.7.1 The general requirements for machinery seatings are given in *Pt 3, Ch 2, 6.9 Machinery seatings*, *see also Pt 9, Ch 1, 5 Securing of machinery*.

5.7.2 Engine holding-down bolts are to be arranged as near as practicable to floors and longitudinal girders. When this cannot be achieved, bracket floors are to be fitted.

5.7.3 Welding in way of machinery seatings is to be double continuous and/or full penetration where appropriate.

5.8 Drainholes in bottom structure

5.8.1 Sufficient limber holes are to be cut in the internal bottom structure to allow for the drainage of water from all parts of the bilge to the pump suctions.

5.8.2 Particular attention is to be given to the positioning of limber holes to ensure adequate drainage and to avoid stress concentrations.

5.8.3 Suitable arrangements are to be made to provide free passage of air from all parts of tanks to the air pipes.

5.9 Rudder horns

5.9.1 The shell plating thickness in way of the rudder horn is to be increased locally, by generally not less than 50 per cent but need not to be taken as greater than the keel thickness required by *Pt 7, Ch 3, 3.2 Plate keel*.

5.9.2 The scantlings of the rudder horn are to be such that the section modulus against transverse bending at any horizontal section XX (*see Figure 3.5.1 Rudder horn*) is not less than:

$$Z = 2,8 k_a R_A K_V (V+3)^2 \sqrt{a^2 + 0,5b^2} \text{ cm}^3$$

where

R_A = total rudder area, in m^2

V = Maximum speed in the fully loaded condition, in knots

K_V = 1,0 for displacement craft with $\frac{V}{\sqrt{L_{WL}}} < 3,0$

= $(1,12 - 0,005\,V)^3$ for planing and semi-planing craft with $\frac{V}{\sqrt{L_{WL}}} \geq 3,0$

a, b = dimensions, in metres, as given in *Figure 3.5.1 Rudder horn*

L_{WL} = waterline length as defined in *Pt 3, Ch 1, 6.2 Principal particulars 6.2.5*

5.9.3 Rudder horns are to be effectively integrated into the adjacent structure and their design is to be such as to facilitate this.

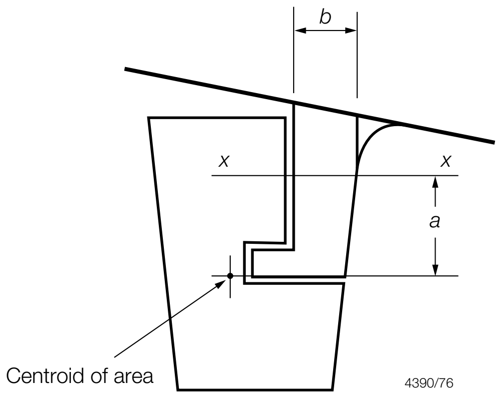


Figure 3.5.1 Rudder horn

5.10 Sternframes

5.10.1 The scantlings of fabricated and forged/solid sternframes are to comply with the requirements of *Pt 3, Ch 3, 3 Sternframes and appendages* modified for appropriate grade of aluminium in accordance with *Pt 3, Ch 3, 1.2 General*.

5.11 Skeg construction

5.11.1 Skegs are to be effectively integrated into the adjacent structure and their design is to be such as to facilitate this.

5.11.2 The scantlings and arrangements for skegs (solepieces) are to be in accordance with *Pt 3, Ch 3, 3.14 Solepieces*.

5.11.3 The scantlings of skegs are to be sufficient to withstand any docking forces that they may be subjected to.

5.12 Forefoot and stem

5.12.1 The thickness of plate stems at the waterline is to comply with the requirements for plate keels as given in *Pt 7, Ch 3, 3.2 Plate keel*.

5.12.2 The forefoot and stem is to be additionally reinforced with floors.

5.12.3 The cross-sectional area of bar stems, A_{bs}, is not to be taken as less than:

$$A_{bs} = 1,5 k_a L_R \text{ cm}^2$$

where

L_R and k_a are as defined in *Pt 7, Ch 3, 1.5 Symbols and definitions 1.5.1*.

5.13 Transom knee

5.13.1 Centre and side girders are to be bracketed to the transom framing members by means of substantial knees. The face flat of the girders may be gradually reduced to that of the transom stiffening members in accordance with *Figure 3.5.2 Transom knee*.

5.13.2 Hard spots are to be avoided in way of the end connections and care is to be taken to ensure that the stiffening member to which the transom knee is bracketed can satisfactorily carry the transmitted loads.

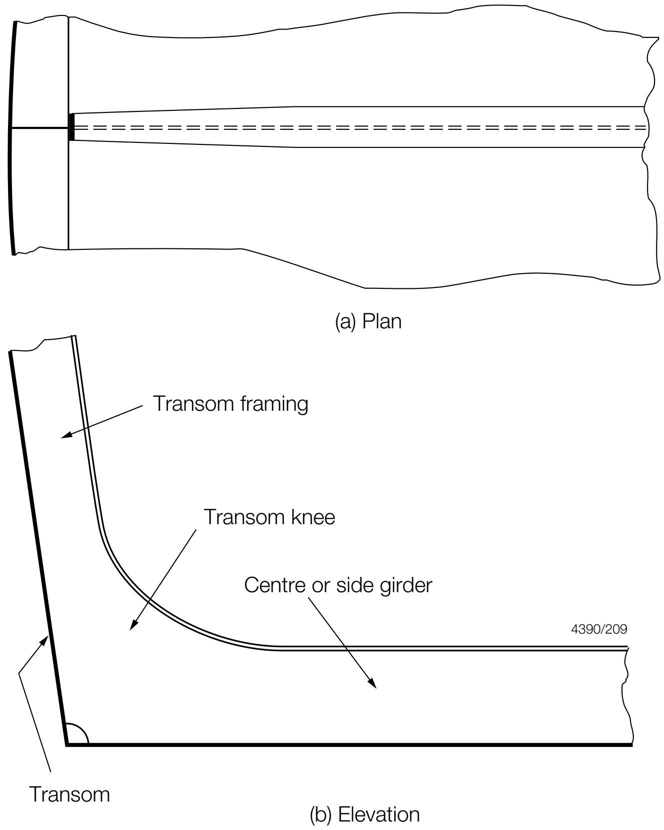


Figure 3.5.2 Transom knee

Section 6
Double bottom structure

6.1 General

6.1.1 The requirements given in this Section provide for double bottom construction of aluminium mono-hull craft in association with either transverse or longitudinal framing.

6.1.2 Double bottoms are generally to be fitted in accordance with *Pt 3, Ch 2, 6.6 Double and single bottom structure* and where fitted are to extend from the collision bulkhead to the after peak bulkhead, as far as this is practicable within the design and proper working of the craft. In addition, the inner bottom is to be continued to the craft's side in such a manner as to protect the bottom to the turn of bilge or chine.

6.1.3 The double bottom structure in way of girders and duct keels is to be sufficient to withstand the forces imposed by dry-docking the craft.

6.1.4 The centreline girder and side girders are to extend as far forward and aft as practicable and care is to be taken to avoid any abrupt discontinuity. Where girders are cut at bulkheads, their longitudinal strength is to be maintained.

6.1.5 The scantlings of the double bottom structure are to comply with the appropriate minimum requirements given in *Pt 7, Ch 3, 2 Minimum thickness requirements*.

6.2 Keel

6.2.1 The scantlings of bar and plate keels are to comply with the requirements of *Pt 7, Ch 3, 5.3 Centre girder*.

6.2.2 Duct keels, where arranged, are to have a side plate thickness not less than:

$$t = \sqrt{k_a}\left(0,01d_{DB} + 2\right) \text{ mm}$$

but need not be taken as greater than 90 per cent of the centre girder thickness given in *Pt 7, Ch 3, 6.3 Centre girder*.

d_{DB} is the Rule centre girder depth given in *Pt 7, Ch 3, 6.3 Centre girder 6.3.3*

k_a is as defined in *Pt 7, Ch 3, 1.5 Symbols and definitions 1.5.1*.

6.2.3 Where a duct keel forms the boundary of a tank, the requirements of *Pt 7, Ch 3, 7.4 Deep tank plating* and *Pt 7, Ch 3, 7.5 Deep tank stiffening* for deep tanks are to be complied with.

6.2.4 The duct keel width is in general to be 15 per cent of the beam or 2 m, whichever is the lesser, but in no case is it to be taken as less than 630 mm. The inner bottom and bottom shell within the duct keel are to be suitably stiffened with primary stiffening in the transverse direction, whilst the continuity of the floors is maintained. Access to the duct keel is to be by means of watertight manholes or trunks.

6.3 Centre girder

6.3.1 A centre girder is to be fitted throughout the length of the craft. The web thickness, t_w, is not to be less than that required by:

$$t = \sqrt{k_a}\left(0,14L_R + 4\right) \text{ mm within } 0,4L_R \text{ amidships}$$
$$= \sqrt{k_a}\left(0,14L_R + 2,75\right) \text{ mm at ends.}$$

where k_a and L_R are as defined in *Pt 7, Ch 3, 1.5 Symbols and definitions 1.5.1*.

6.3.2 The geometric properties of the girder section are to be in accordance with *Pt 7, Ch 3, 1.18 Geometric properties and proportions of stiffener sections*.

6.3.3 The overall depth of the centre girder, d_{DB}, is to be taken as not less than 630 mm and is to be sufficient to give adequate access to all parts of the double bottom.

6.3.4 Additionally, the requirements of *Pt 7, Ch 3, 4.3 Bottom longitudinal primary stiffeners* for bottom longitudinal primary stiffeners are to be complied with.

6.4 Side girders

6.4.1 Where the floor breadth does not exceed 6,0 m, side girders are not required. Vertical stiffeners are to be fitted to the floors on each side, the number and positions of these stiffeners being dependent on the arrangement of the double bottom structure.

6.4.2 Where the breadth of floor is greater than 6,0 m, additional side girders having the same thickness as the floors are to be fitted. The number of side girders is to be such that the distance between the side girders and centre girder and margin plate, or between the side girders themselves, does not exceed 3,0 m.

6.4.3 Side girders where fitted are to extend as far forward and aft as practicable and are in general to terminate in way of bulkheads, deep floors or other primary transverse structure.

6.4.4 Where additional side girders are fitted in way of main machinery seatings, they are to be integrated into the structure of the craft and extended forward and aft as far as practicable.

6.4.5 Under the main engine, girders extending from the bottom shell to the top plate of the engine seating are to be fitted. The height of the girders is to be not less than the height of the floor. Engine holding-down bolts are to be arranged as near as practicable to the girders and floors. Where this cannot be achieved, bracket floors and/or hanging brackets are to be fitted.

6.4.6 Additionally, the requirements of *Pt 7, Ch 3, 4.3 Bottom longitudinal primary stiffeners* for bottom longitudinal primary stiffeners are to be complied with.

6.5 Plate floors

6.5.1 The web thickness of non-watertight plate floors, t_w, is to be not less than:

$$t_w = \sqrt{k_a}\left(0,07L_R + 4,75\right) \text{ mm}$$

where k_a and L are as defined in *Pt 7, Ch 3, 1.5 Symbols and definitions 1.5.1*.

6.5.2 Additionally, the requirements of *Pt 7, Ch 3, 4.6 Bottom transverse web frames* for bottom transverse web frames stiffeners are to be complied with.

6.5.3 Plate floors are, in general, to be continuous between the centre girder and the margin plate.

6.5.4 In longitudinally framed craft, plate floors or equivalent structure are in general to be fitted in the following positions:

(a) At every half frame in way of the main engines, thrust bearings and bottom of the craft forward.
(b) Outboard of the engine seatings, at every frame within the engine room.
(c) Underneath pillars and bulkheads.
(d) Outside of the engine room at a spacing not exceeding 2,0 m.

6.5.5 Vertical flat bar stiffeners are to be fitted to all plate floors at each longitudinal. Each stiffener is to have a depth of not less than $10t_{\text{w}}$ and a thickness of not less than t_{w}, where t_{w} is thickness of the plate floor as calculated in *Pt 7, Ch 3, 6.5 Plate floors 6.5.1*.

6.5.6 In transversely framed craft, plate floors are to be fitted at every frame in the engine room, under bulkheads, in way of change in depth of double bottom and elsewhere at a spacing not exceeding 2,0 m.

6.6 Bracket floors

6.6.1 Between plate floors, the shell and inner bottom plating is to be supported by bracket floors. The brackets are to have the same thickness as plate floors and are to be stiffened on the unsupported edge.

6.6.2 In longitudinally framed craft, the brackets are to extend from the centre girder and margin plate to the adjacent longitudinal, but in no case is the breadth of the bracket to be taken as not less than 75 per cent of the depth of the centre girder. They are to be fitted at every web frame at the margin plate, and those at the centre girder are to be spaced not more than 1,0 m apart.

6.6.3 In transversely framed craft, the breadth of the brackets, attaching the bottom and inner bottom frames to the centre girder and margin plate, is to be not less than 75 per cent of the depth of the centre girder.

6.7 Watertight floors

6.7.1 The scantlings of watertight floors are to comply with the requirements for plate floors as given in *Pt 7, Ch 3, 6.5 Plate floors*.

6.7.2 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deep tanks as detailed in *Pt 7, Ch 3, 7.3 Watertight bulkhead stiffening* or *Pt 7, Ch 3, 7.5 Deep tank stiffening* respectively.

6.8 Tankside brackets

6.8.1 The scantlings of tankside brackets are to comply with the requirements for plate floors given in *Pt 7, Ch 3, 6.5 Plate floors*.

6.9 Inner bottom plating

6.9.1 The thickness of the inner bottom plating is to be determined from the general plating equation given in *Pt 7, Ch 3, 1.16 Plating general* using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

6.9.2 Inner bottom plating forming the boundaries of tank spaces is, in addition, to comply with the requirements for watertight bulkheads or deeptanks as detailed in *Pt 7, Ch 3, 7.2 Watertight bulkhead plating* or *Pt 7, Ch 3, 7.4 Deep tank plating* respectively. Where the plating forms vehicle, passenger or other decks the requirements of *Pt 7, Ch 3, 8 Deck structures* are to be complied with.

6.9.3 Inner bottom longitudinals are to be supported by inner bottom transverse web frames, floors, bulkheads or other primary structure, generally spaced not more than 2 m apart.

6.9.4 The inner bottom longitudinals are to be continuous through the supporting structure and are to be satisfactorily stiffened against buckling.

6.9.5 Where it is impracticable to comply with the requirements of *Pt 7, Ch 3, 6.9 Inner bottom plating 6.9.4*, or where it is desired to terminate the inner bottom longitudinals in way of bulkheads or integral tank boundaries, they are to be bracketed in

way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

6.9.6 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 7, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (b).

6.10 Inner bottom transverse web framing

6.10.1 Inner bottom transverse web frames are defined as primary stiffening members which support inner bottom longitudinals. They are to be continuous and to be substantially bracketed at their end connections to bottom web frames, bottom floors and tankside brackets.

6.10.2 Where it is impracticable to comply with the requirements of *Pt 7, Ch 3, 6.10 Inner bottom transverse web framing 6.10.1*, or where it is desired to terminate the inner bottom transverse web frames in way of centre or side girders, bulkheads or integral tank boundaries, etc. they are to be bracketed in way of their end connections, to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

6.10.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 7, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (a).

6.11 Margin plates

6.11.1 A margin plate, if fitted, is to have a thickness as required for inner bottom plating.

6.12 Wells

6.12.1 Small wells constructed in the double bottom structure are not to extend in depth more than necessary. A well extending to the outer bottom may, however, be permitted at the after end of the shaft tunnel of the craft. Other well arrangements (e.g. for lubricating oil under main engines) may be considered provided they give protection equivalent to that afforded by the double bottom.

6.13 Transmission of pillar loads

6.13.1 In double bottoms under widely spaced pillars, the connections of the floors to the girders, and of the floors and girders to the inner bottom, are to be suitably increased. Where pillars are not directly above the intersection of plate floors and girders, partial floors and intercostals are to be fitted as necessary to support the pillars. Manholes are not to be cut in the floors and girders below the heels of pillars. Where longitudinal framing is adopted in the double bottom, equivalent stiffening under the heels of pillars is to be provided, and where the heels of pillars are carried on a tunnel, suitable arrangements are to be made to support the load.

6.14 Manholes

6.14.1 Sufficient manholes are to be cut in the inner bottom, floors and side girders to provide adequate access to, and ventilation of, all parts of the double bottom. The size of the manhole openings is not, in general, to exceed 50 per cent of the double bottom depth unless edge reinforcement is provided. Holes are not to be cut in the centre girder, except in tanks at the forward and after ends of the craft, and elsewhere where tank widths are reduced unless additional stiffening and/or compensation is fitted to maintain the structural integrity.

6.15 Pressure testing

6.15.1 Double bottoms are to be tested upon completion with a head of water representing the maximum internal pressure which could be experienced in service, but not less than a head of water equivalent to the level of the upper deck.

6.16 Drainholes in bottom structure

6.16.1 Sufficient limber holes are to be cut in the internal bottom structure to allow for the drainage of water from all parts of the bilge to the pump suctions.

6.16.2 Particular care is to be given to the positioning of limber holes to ensure adequate drainage and to avoid stress concentrations.

6.16.3 Suitable arrangements are to be made to provide free passage of air from all parts of tanks to the air pipes.

■ *Section 7* **Bulkheads and deep tanks**

7.1 General

7.1.1 The requirements of this Section apply to a vertical system of stiffening on bulkheads. They may also be applied to a horizontal system of stiffening provided that equivalent support and alignment are provided.

7.1.2 The number and disposition of transverse watertight bulkheads are to be in accordance with *Pt 3, Ch 2, 4 Bulkhead arrangements*.

7.1.3 Bulkheads, or part bulkheads, forming the boundary of tanks are to comply with the requirements of *Pt 7, Ch 3, 7.5 Deep tank stiffening* and *Pt 7, Ch 3, 7.6 Double bottom tanks*.

7.1.4 For bulkheads in way of partially filled holds or tanks, sloshing forces may be required to be taken into account. Where such forces are likely to be significant, the scantlings will be required to be verified by additional calculations.

7.1.5 A centreline bulkhead is, generally, to be fitted in deep tanks which extend from side to side. The bulkhead may be intact or perforated as desired. If intact, the scantlings are to comply with the requirements of *Pt 7, Ch 3, 7.5 Deep tank stiffening* and *Pt 7, Ch 3, 7.6 Double bottom tanks* for tank boundary bulkheads. If perforated, they are to comply with the requirements of *Pt 7, Ch 3, 7.13 Wash plates* for washplates.

7.1.6 The minimum requirements in *Pt 7, Ch 3, 2 Minimum thickness requirements* are to be complied with.

7.2 Watertight bulkhead plating

7.2.1 The thickness of the watertight bulkhead plating is to be determined from the general plating equation given in *Pt 7, Ch 3, 1.16 Plating general* using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

7.3 Watertight bulkhead stiffening

7.3.1 The Rule requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 7, Ch 3, 1.17 Stiffening general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* using the appropriate load model.

7.3.2 Bulkheads are to be suitably strengthened, if necessary, at the ends of deck girders and where subjected to concentrated loads.

7.4 Deep tank plating

7.4.1 The thickness of deep tank plating is to be determined from the general plating equation given in *Pt 7, Ch 3, 1.16 Plating general* using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

7.4.2 A centreline bulkhead is, generally, to be fitted in deep tanks which extend from side to side of the craft. The bulkhead may be intact or perforated as desired. If intact, the plate scantlings are to be as required for boundary bulkheads.

7.5 Deep tank stiffening

7.5.1 Deep tank bulkhead stiffeners are to be bracketed at both ends.

7.5.2 Stiffening on a perforated centreline bulkhead in a tank that extends from side to side may be 50 per cent of that required for boundary bulkheads, using a head measured to the crown of the tank.

7.5.3 The Rule requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 7, Ch 3, 1.17 Stiffening general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for load model (b).

7.6 Double bottom tanks

7.6.1 The scantlings of double bottom tanks are to comply with the requirements for deep tanks given in *Pt 7, Ch 3, 7.4 Deep tank plating* and *Pt 7, Ch 3, 7.5 Deep tank stiffening*.

7.6.2 Where the crown of a double bottom tank forms a vehicle, passenger or other deck, the requirements of *Pt 7, Ch 3, 8 Deck structures* are to be complied with.

7.7 Collision bulkheads

7.7.1 The scantlings of collision bulkheads are to comply with the requirements of *Pt 7, Ch 3, 7.2 Watertight bulkhead plating* and *Pt 7, Ch 3, 7.3 Watertight bulkhead stiffening* except that the thickness of plating and modulus of stiffeners are not to be less than 12 and 25 per cent greater respectively, than required by *Pt 7, Ch 3, 7.2 Watertight bulkhead plating* and *Pt 7, Ch 3, 7.3 Watertight bulkhead stiffening*. If the collision bulkhead forms the boundary of a deep tank or cofferdam then the requirements of *Pt 7, Ch 3, 7.4 Deep tank plating* and *Pt 7, Ch 3, 7.4 Deep tank plating* are also to be complied with.

7.8 Gastight bulkheads

7.8.1 Where gastight bulkheads are fitted, in accordance with *Pt 3, Ch 2, 4 Bulkhead arrangements* the scantling requirements for watertight bulkheads are to be complied with.

7.8.2 Gastight bulkheads are to be fitted to protect accommodation spaces from gases and vapour fumes from machinery exhaust and fuel systems.

7.9 Non-watertight or partial bulkheads

7.9.1 Where a bulkhead is structural but non-watertight the scantlings are in general to be as for watertight bulkheads or equivalent in strength to web frames in the same position. Partial bulkheads that are non-structural are outside the scope of classification.

7.10 Transmission of pillar loads

7.10.1 Bulkheads that are required to act as pillars in way of underdeck girders and other structures subject to heavy loads are to comply with the requirements of *Pt 7, Ch 3, 10 Pillars and pillar bulkheads*.

7.11 Corrugated bulkheads

7.11.1 The plating thickness and section modulus for symmetrical corrugated bulkheads are to be in accordance with watertight bulkheads or deep tank bulkheads as appropriate. The spacing, s, is to be taken as s_c, as defined in *Figure 2.3.1 Corrugation* .

7.11.2 In addition, the section geometric properties of *Pt 7, Ch 3, 1.18 Geometric properties and proportions of stiffener sections* are to be complied with.

7.11.3 The actual section modulus may be derived in accordance with *Pt 3, Ch 2, 3.2 Geometric properties of sections*.

7.12 Stiffeners passing through bulkheads

7.12.1 Primary longitudinal stiffening members are to be continuous through transverse bulkheads.

7.12.2 Pipe or cable runs through watertight bulkheads are to be fitted with suitable watertight glands.

7.13 Wash plates

7.13.1 Tanks are to be subdivided as necessary by internal baffles or wash plates. Baffles or wash plates which support hull framing are to have scantlings equivalent to web frames in the same position.

7.13.2 Wash plates and wash bulkheads are, in general, to have an area of perforation not less than 10 per cent of the total area of the bulkhead. The perforations are to be so arranged that the efficiency of the bulkhead as a support is not impaired.

7.13.3 The plate thickness is to be not less than the structural element from which the wash bulkhead is formed.

7.13.4 The general stiffener requirements are to be in accordance with *Pt 7, Ch 3, 7.5 Deep tank stiffening*. However, the section modulus may be 50 per cent of that required by *Pt 7, Ch 3, 7.5 Deep tank stiffening*.

7.14 Cofferdams

7.14.1 A cofferdam is to be fitted between freshwater and fuel oil or sanitary tanks.The scantlings of cofferdams are to comply with the requirements of deep tank bulkheads or non-watertight bulkheads as appropriate.

7.15 Coatings

7.15.1 Integral freshwater and fuel oil tanks need not in general be coated provided they are constructed from suitable marine grade aluminium alloys in accordance with *Ch 8 Aluminium Alloys* of the Rules for Materials. Where tanks are to be coated, then all surfaces are to be cleaned and dried after testing and then treated with a suitable coating in accordance with the coating manufacturer's recommendations. *See Pt 7, Ch 2, 2.6 Paints and coatings*.

7.16 Air pipes

7.16.1 Air pipes of sufficient number and area are to be fitted to each tank in accordance with *Pt 15, Ch 2, 11 Air, overflow and sounding pipes*.

7.17 Fire protection

7.17.1 Fire protection requirements given in *Pt 17 Fire Protection, Detection and Extinction* are to be complied with.

7.18 Access

7.18.1 Compartments within the craft are to be accessible in order to facilitate proper maintenance and future structural surveys. Linings on craft sides, deckheads and bulkheads etc. must be capable of being removed. Similarly sufficient space must be available below lower decks/soles to provide proper access to the bottom structure. An adequate number of manholes, removable panels etc. are to be provided.

7.18.2 Doors and hatches fitted through watertight bulkheads are to be of equivalent construction to the bulkhead in which they are fitted, to be permanently attached and capable of being closed watertight from both sides of the bulkhead. They are to be tested watertight.

7.18.3 Doors and hatches are not to be fitted in collision bulkheads, except in craft of less than 21 metres Rule length or where it would be impracticable to arrange access to the forepeak other than through the collision bulkhead. Where fitted, the doors and hatches are to be watertight, as small as practicable and open into the forepaw compartment. Doors in collision bulkheads are to be kept closed at all times while the craft is at sea, *see Pt 3, Ch 2, 4.3 Collision bulkhead 4.3.4*.

7.18.4 Particular attention is to be given to the design and workmanship of the tanks, and adequate access manholes are to be fitted, *see Pt 3, Ch 1, 7 Inspection, workmanship and testing procedures*.

7.19 Testing

7.19.1 Deep tanks are to be tested on completion, with a head of water to the top of the overflow, or 1,8 m above the crown of the tank, whichever is the greater. The pressure to which the tanks will be subjected in service is to be indicated on the plans submitted.

■ *Section 8*
Deck structures

8.1 General

8.1.1 The deck plating is to be supported by transverse beams with fore and aft girders or by longitudinals with deep transverse beams. The transverse and deep transverse beams are to align with side main frames and side web frames respectively.

8.1.2 Beams are to be fitted at every frame and bracketed to the frames. Strong beams and deep transverse beams are to align with and be effectively connected to the side web frames. They are also to be fitted at the ends of large openings in the deck.

8.1.3 The deck plating and supporting structure are to be suitably reinforced in way of cranes, masts, derrick posts and deck machinery.

8.1.4 Primary stiffening members are to be continuous and substantially bracketed at their end connections to maintain continuity of structural strength.

8.1.5 Secondary stiffening members are to be effectively continuous and bracketed at their end connections as appropriate.

8.1.6 Primary and secondary stiffener end connection arrangements are, in general, to be in accordance with *Pt 7, Ch 3, 1.22 Primary member end connections* and *Pt 7, Ch 3, 1.20 Secondary member end connections*, respectively.

8.1.7 The ends of beams, longitudinals, girders and transverses are to be effectively built into the adjacent structure, or equivalent arrangements provided.

8.1.8 Tripping brackets are to be fitted on deep webs.

8.1.9 Deck structures subject to concentrated loads, are to be suitably reinforced. Where concentrations of loading on one side of a stiffening member may occur, such as pillars out of line, the member is to be adequately stiffened against torsion. Additional reinforcements may be required in way of localised areas of high stress.

8.1.10 The thickness of the deck plating is in no case to be less than the appropriate minimum requirement given in *Pt 7, Ch 3, 2 Minimum thickness requirements*.

8.1.11 The geometric properties of stiffener sections are to be in accordance with *Pt 7, Ch 3, 1.18 Geometric properties and proportions of stiffener sections*.

8.2 Strength/weather deck plating

8.2.1 The thickness of strength/weather deck plating is to be determined from the general plating equation given in *Pt 7, Ch 3, 1.16 Plating general* using the design pressure head from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

8.2.2 The scantlings of watertight cockpits are to be of equivalent strength to those of the strength/weather deck. *See also Pt 4 Additional Requirements for Yachts*.

8.2.3 It is recommended that the working areas of the weather deck have an anti-slip surface.

8.2.4 Where decks are sheathed with wood or other materials, details of the method of attachment are to be submitted. *See also Pt 7, Ch 3, 2.4 Sheathing*.

8.3 Lower deck/inside deckhouse plating

8.3.1 The thickness of the lower deck/inside deckhouse plating is to be determined from the general plating equation given in *Pt 7, Ch 3, 1.16 Plating general* using the design pressure head from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

8.4 Accommodation deck plating

8.4.1 Accommodation decks are in general to be treated as lower deck/inside deckhouse decks, with their plating requirements determined in accordance with *Pt 7, Ch 3, 8.3 Lower deck/inside deckhouse plating*.

8.5 Cargo deck plating

8.5.1 The thickness of cargo deck plating is to be determined from the general plating equation given in *Pt 7, Ch 3, 1.16 Plating general* using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

8.5.2 For vehicle decks the plating thickness is to comply with *Pt 7, Ch 3, 5.3 Centre girder*.

8.6 Decks forming crowns of tanks

8.6.1 Decks forming the crown of tanks are to comply with the requirements for the appropriate deck, and are to be additionally examined for compliance with the requirements for deep tank plating given in *Pt 7, Ch 3, 7.4 Deep tank plating*.

8.7 Strength/weather deck stiffening

8.7.1 The Rule requirements for section modulus, inertia and web area for the **strength/weather deck primary stiffening** are to be determined from the general equations given in *Pt 7, Ch 3, 1.17 Stiffening general*, using the design pressure heads from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (a).

8.7.2 The Rule requirements for section modulus, inertia and web area for the **strength/weather deck secondary stiffening** are to be determined from the general equations given in *Pt 7, Ch 3, 1.17 Stiffening general*, using the design pressure heads from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.7.3 Longitudinal framing is, in general, to be adopted at the strength deck outside line of openings, but special consideration will be given to proposals for transverse framing.

8.8 Lower deck/inside deckhouse stiffening

8.8.1 The Rule requirements for section modulus, inertia and web area for lower deck/inside deckhouse stiffening are to be determined from the general equations given in *Pt 7, Ch 3, 1.17 Stiffening general* using the design pressure head from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients*. Primary members are assumed to be load model (a) and secondary members load model (b). However, special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.9 Accommodation deck stiffening

8.9.1 Accommodation decks are in general to be treated as lower deck/inside deckhouse decks, with their scantling requirements determined in accordance with *Pt 7, Ch 3, 8.8 Lower deck/inside deckhouse stiffening*.

8.10 Cargo deck stiffening

8.10.1 The Rule requirements for section modulus, inertia and web area for cargo deck stiffening are to be determined from the general equations given in *Pt 7, Ch 3, 1.17 Stiffening general* using the design pressure head from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate and the coefficients $\boldsymbol{\Phi}_Z$, $\boldsymbol{\Phi}_I$, and $\boldsymbol{\Phi}_A$ as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients*. Primary members are assumed to be load model (a) and secondary members load model (b). However, special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.10.2 In addition, where the cargo comprises wheeled vehicles, the requirements of *Pt 7, Ch 5, 3 Vehicle decks* are to be complied with.

8.11 Deck openings

8.11.1 All openings are to be supported by an adequate framing system, pillars or cantilevers. When cantilevers are used scantlings may be derived from direct calculations.

8.11.2 Where stiffening members terminate in way of an opening they are to be attached to carlings, girders, transverses or coaming plates.

8.11.3 The corners of large hatchways in the strength/weather deck within 0,5L_R amidships are to be elliptical, parabolic or rounded, with a radius generally not less than 1/24 of the breadth of the opening.

8.11.4 Where elliptical corners are arranged, the major axis is to be fore and aft, the ratio of the major to minor axis is to be not less than two to one nor greater than 2,5 to one, and the minimum half-length of the major axis is to be defined by l_1 in *Figure 3.8.1 Hatch opening geometry*. Where parabolic corners are arranged, the dimensions are also to be as shown in *Figure 3.8.1 Hatch opening geometry*.

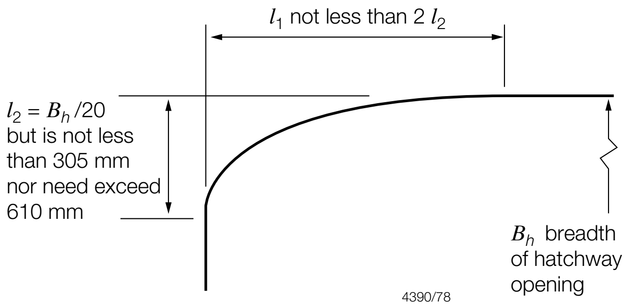


Figure 3.8.1 Hatch opening geometry

8.11.5 Where the corners are parabolic or elliptical, insert plates are not required.

8.11.6 For other shapes of corner, insert plates of the size and extent shown in *Figure 3.8.2 Inserts in way of hatch opening*will, in general, be required. The required thickness of the insert plate is to be not less than 25 per cent greater than the adjacent deck thickness, outside line of openings.

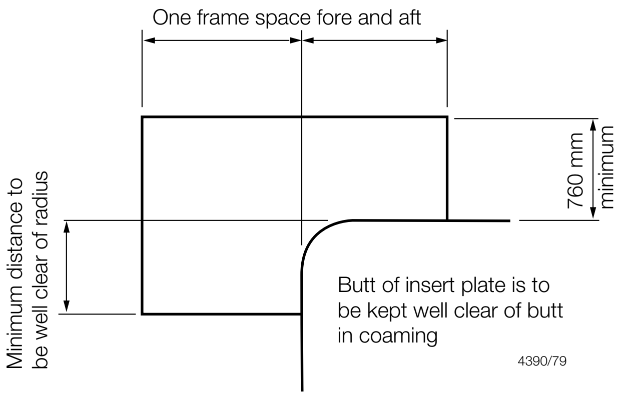


Figure 3.8.2 Inserts in way of hatch opening

8.11.7 For lower decks the corners of large openings are to be rounded, with a radius generally not less than 1/24 of the breadth of the opening.

8.11.8 Insert plates will be required at lower decks in way of any rapid change in hull form to compensate for loss of deck cross-sectional area. Otherwise, insert plates will not normally be required.

8.11.9 Adequate transverse strength is to be provided in the deck area between large hatch openings, subjected to transverse and buckling loads.

8.11.10 The requirements for closing arrangements and outfit are given in *Pt 3, Ch 4 Closing Arrangements and Outfit*.

8.12 Sheathing

8.12.1 The requirements for deck sheathing given in *Pt 7, Ch 3, 2.4 Sheathing* are to be complied with.

8.13 Novel features

8.13.1 Where large or novel hatch openings are proposed, detailed calculations are to be submitted to demonstrate that the scantlings and arrangements in way of the openings are adequate to maintain continuity of structural strength.

Section 9
Superstructures, deckhouses and bulwarks

9.1 General

9.1.1 Where practicable, superstructures and deckhouses are to be designed with well cambered decks and well radiused corners to build rigidity into the structure.

9.1.2 The plating and supporting structure are to be suitably reinforced in way of localised areas of high stress such as corners of openings, cranes, masts, derrick posts, machinery, fittings and other heavy or vibrating loads.

9.1.3 Primary stiffening members are to be continuous and substantially bracketed at their end connections to maintain continuity of structural strength.

9.1.4 Secondary stiffening members are to be effectively continuous and bracketed at their end connections as appropriate.

9.1.5 Structures subject to concentrated loads are to be suitably reinforced. Where concentrations of loading on one side of a stiffener may occur, such as pillars out of line, the stiffener is to be adequately stiffened against torsion.

9.1.6 The plating thickness of superstructures, deckhouses and bulwarks is no case to be less than the appropriate minimum requirement given in *Pt 7, Ch 3, 2 Minimum thickness requirements*.

9.1.7 Stiffener sections and geometric properties are to be in accordance with *Pt 7, Ch 3, 1.18 Geometric properties and proportions of stiffener sections*.

9.2 Symbols and definitions

9.2.1 The term `house' is used in this Section to include both superstructures and deckhouses.

9.2.2 The symbols applicable to this Section are defined in *Pt 7, Ch 3, 1.5 Symbols and definitions 1.5.1*.

9.3 House side plating

9.3.1 The thickness of house side plating is to be determined from the general plating equation given in *Pt 7, Ch 3, 1.16 Plating general* using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

9.4 House front plating

9.4.1 The thickness of the house front plating is to be determined from the general plating equation given in *Pt 7, Ch 3, 1.16 Plating general* using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

9.5 House end plating

9.5.1 The thickness of the house end plating is to be determined from the general plating equation given in *Pt 7, Ch 3, 1.16 Plating general* using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

9.6 House top plating

9.6.1 The thickness of the house top plating is to be determined from the general plating equation given in *Pt 7, Ch 3, 1.16 Plating general* using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

9.7 Coachroof plating

9.7.1 The thickness of the coachroof plating is to be determined from the general plating equation given in *Pt 7, Ch 3, 1.16 Plating general* using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

9.8 Machinery casing plating

9.8.1 The thickness of the plating of machinery casings is to be determined from the general plating equation given in *Pt 7, Ch 3, 1.16 Plating general* using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

9.9 Forecastle requirements

9.9.1 The forecastle side plating may be a continuation of the hull side shell plating or fitted as a separate assembly. In both cases the plating thickness is to be the same as the side shell plating at deck edge. Where fitted as a separate assembly, suitable arrangements are to be made to ensure continuity of the effect of the sheerstrake at the break and at the upper edge of the forecastle side. Full penetration welding is to be used.

9.9.2 The side plating is to be stiffened by side frames effectively connected to the deck structure. Deep webs are to be fitted to ensure overall rigidity.

9.9.3 The deck plating thickness is to be increased by 20 per cent in way of the end of the forecastle if this occurs at a position aft of $0{,}25L_R$ from the F.P. No increase is required if the forecastle end bulkhead lies forward of $0{,}2L_R$ from the F.P. The increase at intermediate positions of end bulkhead is to be obtained by interpolation.

9.10 House side stiffeners

9.10.1 The Rule requirements for section modulus, inertia and web area for the **house side primary stiffening** are to be determined from the general equations given in *Pt 7, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (a).

9.10.2 The Rule requirements for section modulus, inertia and web area for **house side secondary stiffening** are to be determined from the general equations given in *Pt 7, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.11 House front stiffeners

9.11.1 The Rule requirements for section modulus, inertia and web area for **house front primary stiffening** are to be determined from the general equations given in *Pt 7, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (a).

9.11.2 The Rule requirements for section modulus, inertia and web area for **house front secondary stiffening** are to be determined from the general equations given in *Pt 7, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.12 House aft end stiffeners

9.12.1 The Rule requirements for section modulus, inertia and web area for **house aft end primary stiffening** are to be determined from the general equations given in *Pt 7, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (a).

9.12.2 The Rule requirements for section modulus, inertia and web area for **house aft end secondary stiffening** are to be determined from the general equations given in *Pt 7, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.13 House top stiffeners

9.13.1 The house top is to be effectively supported by a system of transverse or longitudinal beams and girders. The span of the beams is in general not to exceed 2,4 m and the beams are to be effectively connected to the house upper coamings and girders.

9.13.2 The Rule requirements for section modulus, inertia and web area for **house top primary stiffening** are to be determined from the general equations given in *Pt 7, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (a).

9.13.3 The Rule requirements for section modulus, inertia and web area for **house top secondary stiffening** are to be determined from the general equations given in *Pt 7, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.14 Coachroof stiffeners

9.14.1 The Rule requirements for section modulus, inertia and web area for **coachroof primary stiffening** are to be determined from the general equations given in *Pt 7, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (a).

9.14.2 The Rule requirements for section modulus, inertia and web area for **coachroof secondary stiffening** are to be determined from the general equations given in *Pt 7, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.15 Machinery casing stiffeners

9.15.1 The Rule requirements for section modulus, inertia and web area for **machinery casing primary stiffening** are to be determined from the general equations given in *Pt 7, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (a).

9.15.2 The Rule requirements for section modulus, inertia and web area for **machinery casing secondary stiffening** are to be determined from the general equations given in *Pt 7, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.15.3 Where casing stiffeners carry loads from deck transverses, girders, etc. or where they are in line with pillars below, they are to be suitably reinforced.

9.15.4 Where casing sides act as girders supporting decks over, care is to be taken that access openings do not seriously weaken the structure. Openings are to be effectively framed and reinforced if found necessary. Particular attention is to be paid to stiffening where the casing supports the funnel or exhaust uptakes.

9.16 Forecastle stiffeners

9.16.1 The scantlings of forecastle primary and secondary stiffening members are to be equivalent to those for the side shell envelope framing at the deck edge as required by *Pt 7, Ch 3, 4 Shell envelope framing*.

9.17 Superstructures formed by extending side structures

9.17.1 Superstructure first tier sides formed by extending the hull side structure are to be in accordance with the requirements for house fronts given in *Pt 7, Ch 3, 9.4 House front plating* and *Pt 7, Ch 3, 9.11 House front stiffeners* for plating and stiffeners

respectively, but need not be taken as greater than the side structure requirements at the deck edge at the same longitudinal position.

9.18 Fire aspects

9.18.1 The requirements for fire detection, protection and extinction are given in *Pt 17 Fire Protection, Detection and Extinction*.

9.19 Openings

9.19.1 All openings are to be substantially framed and have well rounded corners. Arrangements are to be made to minimise the effect of discontinuities in erections. Continuous coamings or girders are to be fitted below and above doors and similar openings.

9.19.2 Particular attention is to be paid to the effectiveness of end bulkheads, and the upper deck stiffening in way, when large openings for doors and windows are fitted.

9.19.3 Special care is to be taken to minimise the size and number of openings in the side bulkheads in the region of the ends of erections within $0,5L_R$ amidships. Account is to be taken of the high vertical shear loading which can occur in these areas.

9.19.4 For closing arrangements and outfit the requirements are given in *Pt 3, Ch 4 Closing Arrangements and Outfit*.

9.20 Mullions

9.20.1 Window openings are to be suitably framed and mullions will in general be required.

9.20.2 The scantlings of mullions are to be not less than as required for a stiffener in the same position.

9.20.3 When determining the stiffener requirements, the width of effective plating is in no case to be taken as greater than the distance between adjacent window openings.

9.20.4 Where significant shear forces are to be vertically transmitted by the window frames, adequate shear rigidity is to be verified by direct calculation.

9.21 Global strength

9.21.1 Transverse rigidity is to be maintained throughout the length of the erection by means of web frames, bulkheads or partial bulkheads. Particular attention is to be paid when an upper tier is wider than its supporting tier and when significant loads are carried on the house top.

9.21.2 Where practicable, web frames are to be arranged in line with bulkheads below.

9.21.3 Internal bulkheads are to be fitted in line with bulkheads or deep primary stiffeners below.

9.22 House/deck connection

9.22.1 Adequate support under the ends of erections is to be provided in the form of webs, pillars, diaphragms or bulkheads in conjunction with reinforced deck beams.

9.22.2 Special attention is to be given to the connection of the erection to the deck in order to provide an adequate load distribution and avoid stress concentrations.

9.22.3 Connections between the erection and the deck by means of bimetallic joints are to comply with *Pt 7, Ch 2, 4.27 Aluminium/wood connection*.

9.22.4 Typical design details of house/deck connections are given in LR's *Guidance Notes for Structural Details*.

9.23 Sheathing

9.23.1 Sheathing arrangements are to comply with the requirements of *Pt 7, Ch 3, 2.4 Sheathing*.

9.24 Erections contributing to longitudinal strength

9.24.1 For craft above 40 m in length, L_R, or for designs where the superstructure is designed to absorb global loads the effectiveness of superstructures to carry these loads is to be determined. The effectiveness may be assessed in accordance with *Pt 7, Ch 6, 2.5 Superstructures global strength*.

9.24.2 Where *Pt 7, Ch 3, 9.17 Superstructures formed by extending side structures* applies and the first or second tier is regarded as the strength deck according to *Pt 7, Ch 6, 2.5 Superstructures global strength*, the hull upper deck scantlings at the forward and aft ends of the superstructure may need to be increased due to the lesser efficiency of the superstructure tiers at their ends. The scantlings of the side structure in way of these areas may also need to be increased.

9.24.3 When large openings or a large number of smaller openings are cut in the superstructure sides, reducing the capability to transmit shear force between decks, an assessment of structural efficiency may be required.

9.25 Novel features

9.25.1 Direct calculations may be required to determine the plating and stiffener requirements where the house is of unusual design, form or proportions.

9.26 Bulwarks

9.26.1 General requirements for bulwarks are given in *Pt 3, Ch 4, 8 Bulwarks, guard rails and other means for the protection of crew*.

9.26.2 The thickness of the bulwark plating is to be determined from the general plating equation given in *Pt 7, Ch 3, 1.16 Plating general* using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

9.26.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 7, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (d).

9.26.4 Bulwarks are not to be cut for gangway or other openings near the breaks of superstructures.

9.26.5 Attention is to be paid to avoid discontinuity of strength of the bulwark, particularly in way of local increases in stress and changes in height.

9.26.6 Welding of bulwark to the top edge of sheerstrake within $0{,}5L_R$ amidship, is generally to be avoided. However, if this arrangement is not practicable welding to the sheerstrake may be accepted if care is taken to minimise any notch effects.

9.26.7 **Fishing craft** are to have bulwarks fitted. The bulwark may be formed from a continuation of the side shell plating or connected as a separate assembly. Where the bulwark is considered to be stressed and contributing to the global strength of the craft, the plate thickness of the bulwark is not to be less than the sheerstrake plating thickness. In no case is the thickness of the bulwark plating to be taken as less than 80 per cent of the side shell thickness. The bulwark is to be supported by suitable stiffening members which may be formed from a continuation of the side frames, or from flanged plate stays of the same thickness as the bulwark. In general these frames are to be spaced not more than two side frame spacings apart.

9.26.8 In way of gantries, trawl gallows, mooring pipes etc. the plate thickness in way is to be increased by not less than 50 per cent.

9.26.9 **Pilot craft** are to be fitted with sufficient hand rails adjacent to the exposed areas of the working decks and platforms. In addition these areas are to have non-skid surfaces.

9.27 Freeing arrangements

9.27.1 Requirements for freeing arrangements are given in *Pt 3, Ch 4, 9 Deck drainage*.

9.28 Free flow area

9.28.1 The requirements for the free flow area are given in *Pt 3, Ch 4, 9.3 Free flow area*.

9.29 Guard rails

9.29.1 The requirements for guard rails are given in *Pt 3, Ch 4, 8.4 Guard rails*.

Section 10
Pillars and pillar bulkheads

10.1 Application

10.1.1 Pillars are to be arranged to transmit loads from decks and superstructures into the bottom structure. Pillars are generally to be constructed from solid, tubular, or I beam section. A pillar may be a fabricated trunk or partial bulkhead.

10.2 Determination of span length

10.2.1 The effective span length of the pillar, l_{ep}, is in general the distance between the head and heel of the pillar. Where substantial brackets are fitted, l_{ep} may be reduced by 2/3 the depth of the bracket at each end.

10.3 Head and heel connections

10.3.1 Pillars are to be attached at their heads to plates supported by efficient brackets, in order to transmit the load effectively. Doubling or insert plates are to be fitted to decks under large pillars and to the inner bottom under the heels of tubular or hollow square pillars. The pillars are to have a bearing fit and are to be attached to the head and heel plates by continuous welding. At the heads and heels of pillars built of rolled sections, the load is to be well distributed by means of longitudinal and transverse brackets.

10.4 Alignment and arrangement

10.4.1 Pillars are to be located on main structural members. They are in general to be fitted below windlasses, winches, capstans, the corners of deckhouses and elsewhere where considered necessary.

10.4.2 Wherever possible, deck pillars are to be fitted in the same vertical line as pillars above and below, and effective arrangements are to be made to distribute the load at the heads and heels of all pillars.

10.4.3 Where pillars support eccentric loads, or are subjected to lateral pressures, they are to be suitably strengthened for the additional bending moment imposed upon them.

10.4.4 Doublers are generally to be fitted on decks and inner bottoms, other than within tanks where doublers are not allowed. Brackets may be used instead of doublers.

10.5 Minimum thickness

10.5.1 The minimum wall thickness of hollow pillars is to be taken as not less than 1/20 of the external dimension of the pillar.

10.6 Design loads

10.6.1 The design loading, P_p, is not to be less than:

$$P_p = S_{gt} b_{gt} P_c + P_a \text{ kN}$$

where

P_p = design load supported by the pillar, to be taken as not less than 5 kN

P_c = basic deck girder design pressure, as appropriate, plus any other loadings directly above the pillar, in kN/m^2

P_a = load, in kN, from pillar or pillars above, assumed zero if there are no pillars over

S_{gt} = spacing, or mean spacing, of girders or transverses, in metres

b_{gt} = distance between centres of two adjacent spans of girders or transverses supported by the pillar, in metres

10.7 Scantlings determination

10.7.1 The cross-sectional area of the pillar, A_p, is not to be less than:

$$A_p = 10\frac{P_p}{\sigma_p} \text{ cm}^2$$

where

P_p = design load, in kN, supported by the pillar as determined from *Pt 7, Ch 3, 10.6 Design loads*

σ_p = permissible compressive stress, in N/mm^2

$$= \frac{f_p \sigma_A}{1 + 0{,}015\,\sigma_A k_f \left(\frac{l_{ep}}{r}\right)^2} \text{ N/mm}^2$$

where

f_p = pillar location factor defined in *Table 3.10.1 Pillar location factors*

σ_A = 0,2 per cent proof stress of the alloy in the unwelded condition, in N/mm^2

k_f = pillar end fixity factor

= 0,25 for full fixed/bracketed

= 0,50 for partially fixed

= 1,0 for free ended

r = least radius of gyration of pillar cross-section, in cm, and may be taken as:

$$r = \sqrt{\frac{I_p}{A_p}} \text{ cm}$$

I_p = least moment of inertia of cross-section of pillar or stiffener/plate combination, in cm^4

l_{ep} = effective span of pillar or bulkhead, in metres, as defined in *Pt 7, Ch 3, 10.2 Determination of span length*.

Table 3.10.1 Pillar location factors

Location	f_p
Supporting weather deck	0,50
Supporting vehicle deck	0,50
Supporting passenger deck	0,50
Supporting lower/inner deck	0,75
Supporting coachroof	0,75
Supporting deckhouse top	1,00

10.8 Maximum slenderness ratio

10.8.1 The slenderness ratio (l_{ep}/r) of pillars is not to be taken greater than 1,1, where l_{ep} and r are as defined in *Pt 7, Ch 3, 10.7 Scantlings determination 10.7.1*. Pillars with slenderness ratio in excess of 1,1 may be accepted subject to special consideration on a case by case basis and provided that the remaining requirements of the Rules are complied with.

10.9 Pillars in tanks

10.9.1 In no circumstances are pillars to pass through tanks. Where loads are to be transmitted through tanks, pillars within the tanks are to be carefully aligned with the external pillars.

10.9.2 Pillars within tanks are, in general, to be of solid cross section. Where it is proposed to use hollow section pillars each case will be subject to special consideration and the scantlings as determined from the Rules may require to be increased

dependent upon the material to be used, the fluid contained and the arrangement of the pillars. Hollow pillars are to be adequately drained and vented.

10.9.3 Where pillars within tanks may be subjected to tensile stresses due to hydrostatic pressure, the design is to provide sufficient welding to withstand the tensile load imposed.

10.9.4 Doubling plates at ends of pillars within tanks are not acceptable.

10.10 Pillar bulkheads

10.10.1 The stiffener/plate combination used in the determination of pillar bulkhead scantlings is to be that of a stiffener with an effective width of attached plating as determined from *Pt 7, Ch 3, 1.11 Effective width of attached plating*.

10.10.2 The cross-sectional area of the pillar bulkhead, A_{pb}, is to be determined in accordance with *Pt 7, Ch 3, 10.7 Scantlings determination* using the design loading, P_{pb}, as follows:

$$P_{pb} = S_{bs} b_{pb} P_c + P_a \text{ kN}$$

where

P_{pb} = design load supported by the stiffener plate combination of the pillar bulkhead

P_c = basic deck girder design pressure, as appropriate, plus any other loadings directly above the pillar, in kN/m^2

S_{bs} = spacing, or mean spacing, of bulkheads or effective transverses/longitudinal stiffeners, in metres

b_{pb} = distance between centres of two adjacent spans of girders or transverses supported by the pillar bulkhead, in metres, and can be taken as the distance between pillar bulkhead stiffeners where the stiffeners at the top of the bulkhead effectively distributes the load evenly into the stiffeners

10.10.3 The thickness of the bulkhead plating is in no case to be taken less than 4 mm.

10.11 Direct calculations

10.11.1 As an alternative to *Pt 7, Ch 3, 10.6 Design loads*, pillars may be designed on the basis of direct calculation. The method adopted and the stress levels proposed for the material of construction are to be submitted together with the calculations for consideration.

10.12 Fire aspects

10.12.1 Pillars and pillar bulkheads are to be suitably protected against fire, and, where necessary, be self-extinguishing or capable of resisting fire damage. All pillars are to comply with the requirements of *Pt 17 Fire Protection, Detection and Extinction*.

10.13 Novel features

10.13.1 Where unusual or novel pillar designs are proposed that are unable to comply with the requirements of this Section, their design together with the direct calculations are to be submitted for special consideration.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to multi-hull craft of aluminium construction as defined in *Ch 1, 1 Background*.

1.2 General

1.2.1 Except as otherwise specified within this Chapter, the scantlings and arrangements of multi-hull craft are to be determined in accordance with the procedures described in, or required by *Pt 7, Ch 3 Scantling Determination for Mono-Hull Craft* for mono-hull craft, using the pressures from *Pt 5 Design and Load Criteria* appropriate to multi-hulls.

1.3 Direct calculations

1.3.1 Where the craft is of unusual design, form or proportions, or where the speed of the craft exceeds 60 knots the scantlings are to be determined by direct calculation.

1.3.2 The requirements of this Chapter may be modified where direct calculation procedures are adopted to analyse the stress distribution in the primary structure.

1.4 Equivalents

1.4.1 Lloyd's Register (hereinafter referred to as 'LR') will consider direct calculations for the derivation of scantlings as an alternative and equivalent to those derived by Rule requirements in accordance with *Pt 3, Ch 1, 3 Equivalents*.

1.5 Symbols and definitions

1.5.1 The symbols used in this Chapter are defined below and in the appropriate Section:

L_R = Rule length of craft, in metres

s = stiffener spacing, in mm

t_p = plating thickness, in mm

k_a = alloy factor

= $125/\sigma_a$

σ_a = 0,2 per cent proof stress of the alloy in the welded condition, in N/mm^2

1.5.2 **Bottom outboard**. For high speed craft, where the scantlings of the bottom shell are governed by impact pressure considerations, the bottom outboard shell is defined as the area of the hull between the outboard edge of the keel and the outer bilge tangential point. For displacement and semi displacement type craft where the scantlings of the bottom shell are governed by either hydrostatic or pitching pressures the bottom outboard shell is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

1.5.3 **Bottom inboard**. For high speed craft, where the scantlings of the bottom shell are governed by impact pressure considerations, the bottom inboard shell is defined as the area of the hull between the inboard edge of the keel and the inner bilge tangential point. For displacement and semi displacement type craft where the scantlings of the bottom shell are governed by either hydrostatic or pitching pressures the bottom inboard shell is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

1.5.4 **Cross-deck**. The cross-deck is defined as the structure which forms the bridge connection between any two adjacent hulls.

1.5.5 **Haunch**. The haunch is defined as the transition area between the cross-deck and the inboard side shell plating.

1.5.6 **Side inboard**. The side inboard is defined as the area between the bottom inboard shell and the wet-deck (or lower edge of the haunches, where fitted).

1.5.7 **Side outboard**. The side outboard is defined as the area between bottom outboard shell and the deck at side.

1.5.8 **Wet-deck**. The wet-deck is defined as the area between the upper edges of the side inboard plating (or upper edges of the haunches, where fitted).

■ *Section 2* Minimum thickness requirements

2.1 General

2.1.1 Unless otherwise specified in this Section, the requirements of *Pt 7, Ch 3, 2 Minimum thickness requirements* are to be complied with.

2.1.2 The thickness of plating and stiffeners determined from the Rule requirements is not to be less than the appropriate minimum requirement given in *Table 4.2.1 Minimum thickness requirements* for craft type.

2.1.3 In addition, where plating contributes to the global strength of the craft, the thickness is to be not less than that required to satisfy global strength requirements.

Table 4.2.1 Minimum thickness requirements

Item	Minimum thickness (mm)		
	Catamaran	Multi-hull	Swath
Shell envelope			
Bottom shell plating	$\varphi_s\, \omega \sqrt{k_m}\left(0,7\sqrt{L_R}+1,0\right) \geq 4,0\,\omega$	$\omega \sqrt{k_m}\left(0,7\sqrt{L_R}+1,0\right) \geq 4,0\,\omega$	$\omega \sqrt{k_m}\left(0,7\sqrt{L_R}+1,0\right) \geq 4,0\,\omega$
Side shell plating	$\varphi_s\, \omega \sqrt{k_m}\left(0,5\sqrt{L_R}+1,4\right) \geq 3,5\,\omega$	$\omega \sqrt{k_m}\left(0,5\sqrt{L_R}+1,4\right) \geq 3,5\,\omega$	$\omega \sqrt{k_m}\left(0,5\sqrt{L_R}+1,4\right) \geq 3,5\,\omega$
Wet-deck plating	$\omega \sqrt{k_m}\left(0,5\sqrt{L_R}+1,4\right) \geq 3,5\,\omega$	$\omega \sqrt{k_m}\left(0,5\sqrt{L_R}+1,4\right) \geq 3,5\,\omega$	$\omega \sqrt{k_m}\left(0,5\sqrt{L_R}+1,4\right) \geq 3,5\,\omega$
Single bottom structure			
Centre girder web	$\varphi_p\, \omega \sqrt{k_m}\left(0,8\sqrt{L_R}+1,4\right) \geq 5,0\,\omega$	$\omega \sqrt{k_m}\left(1,1\sqrt{L_R}+1,4\right) \geq 5,0\,\omega$	$\omega \sqrt{k_m}\left(1,1\sqrt{L_R}+1,4\right) \geq 5,0\,\omega$

Floor webs	$\varphi_{\rm p}\,\omega\sqrt{k_{\rm m}}(0{,}6\sqrt{L_{\rm R}}+1{,}3)\geq 4{,}0\,\omega$	$\omega\sqrt{k_{\rm m}}(0,8\sqrt{L_{\rm R}}+1,1)\geq 4,0\,\omega$	$\omega\sqrt{k_{\rm m}}(0,8\sqrt{L_{\rm R}}+1,1)\geq 4,0\,\omega$
Side girder webs	$\varphi_{\rm p}\,\omega\sqrt{k_{\rm m}}(0{,}6\sqrt{L_{\rm R}}+1{,}3)\geq 4{,}0\,\omega$	$\omega\sqrt{k_{\rm m}}(0,8\sqrt{L_{\rm R}}+1,1)\geq 4,0\,\omega$	$\omega\sqrt{k_{\rm m}}(0,8\sqrt{L_{\rm R}}+1,1)\geq 4,0\,\omega$
Double bottom structure Centre girder			
(1) Within 0,4$L_{\rm R}$ amidships	$\omega\sqrt{k_{\rm m}}(1,1\sqrt{L_{\rm R}}+1,4)\geq 5,0\,\omega$	$\omega\sqrt{k_{\rm m}}(1,1\sqrt{L_{\rm R}}+1,4)\geq 5,0\,\omega$	$\omega\sqrt{k_{\rm m}}(1,1\sqrt{L_{\rm R}}+1,4)\geq 5,0\,\omega$
(2) Outside 0,4$L_{\rm R}$ amidships	$\omega\sqrt{k_{\rm m}}(0,95\sqrt{L_{\rm R}}+1,4)\geq 5,0\,\omega$	$\omega\sqrt{k_{\rm m}}(0,95\sqrt{L_{\rm R}}+1,4)\geq 5,0\,\omega$	$\omega\sqrt{k_{\rm m}}(0,95\sqrt{L_{\rm R}}+1,4)\geq 5,0\,\omega$
Floors and side girders	$\omega\sqrt{k_{\rm m}}(0,8\sqrt{L_{\rm R}}+1,1)\geq 4,0\,\omega$	$\omega\sqrt{k_{\rm m}}(0,8\sqrt{L_{\rm R}}+1,1)\geq 4,0\,\omega$	$\omega\sqrt{k_{\rm m}}(0,8\sqrt{L_{\rm R}}+1,1)\geq 4,0\,\omega$
Inner bottom plating	$\omega\sqrt{k_{\rm m}}(0,7\sqrt{L_{\rm R}}+1,3)\geq 3,5\,\omega$	$\omega\sqrt{k_{\rm m}}(0,7\sqrt{L_{\rm R}}+1,3)\geq 3,5\,\omega$	$\omega\sqrt{k_{\rm m}}(0,7\sqrt{L_{\rm R}}+1,3)\geq 3,5\,\omega$
Bulkheads Watertight bulkhead plating	$\omega\sqrt{k_{\rm m}}(0,43\sqrt{L_{\rm R}}+1,2)\geq 3,0\,\omega$	$\omega\sqrt{k_{\rm m}}(0,43\sqrt{L_{\rm R}}+1,2)\geq 3,0\,\omega$	$\omega\sqrt{k_{\rm m}}(0,43\sqrt{L_{\rm R}}+3,0)\geq 3,0\,\omega$
Deep tank bulkhead plating	$\omega\sqrt{k_{\rm m}}(0,5\sqrt{L_{\rm R}}+1,4)\geq 3,5$	$\omega\sqrt{k_{\rm m}}(0,5\sqrt{L_{\rm R}}+1,4)\geq 3,5\,\omega$	$\omega\sqrt{k_{\rm m}}(0,5\sqrt{L_{\rm R}}+1,4)\geq 3,5\,\omega$
Deck plating and stiffeners Strength/Main deck plating	$\varphi_{\rm s}\,\omega\sqrt{k_{\rm m}}(0,5\sqrt{L_{\rm R}}+1,4)\geq 3,5\,\omega$	$\omega\sqrt{k_{\rm m}}(0,5\sqrt{L_{\rm R}}+1,4)\geq 3,5\,\omega$	$\omega\sqrt{k_{\rm m}}(0,5\sqrt{L_{\rm R}}+1,4)\geq 3,5\,\omega$
Lower deck/Inside deckhouse, *see* Note 1	$\varphi_{\rm s}\,\omega\sqrt{k_{\rm m}}(0,3\sqrt{L_{\rm R}}+1,3)\geq 3,0\,\omega$	$\omega\sqrt{k_{\rm m}}(0,3\sqrt{L_{\rm R}}+1,3)\geq 3,0\,\omega$	$\omega\sqrt{k_{\rm m}}(0,3\sqrt{L_{\rm R}}+1,3)\geq 3,0\,\omega$
Superstructures and deckhouses, *see* Note 1 Superstructure side plating	$\varphi_{\rm s}\,\omega\sqrt{k_{\rm m}}(0,4\sqrt{L_{\rm R}}+1,1)\geq 3,0\,\omega$	$\omega\sqrt{k_{\rm m}}(0,4\sqrt{L_{\rm R}}+1,1)\geq 3,0\,\omega$	$\omega\sqrt{k_{\rm m}}(0,4\sqrt{L_{\rm R}}+1,1)\geq 3,0\,\omega$
Deckhouse front 1st tier	$\varphi_{\rm s}\,\omega\sqrt{k_{\rm m}}(0,62\sqrt{L_{\rm R}}+1,8)\geq 3,5\,\omega$	$\omega\sqrt{k_{\rm m}}(0,62\sqrt{L_{\rm R}}+1,8)\geq 3,5\,\omega$	$\omega\sqrt{k_{\rm m}}(0,62\sqrt{L_{\rm R}}+1,8)\geq 3,5\,\omega$
Deckhouse front upper tiers	$\varphi_{\rm s}\,\omega\sqrt{k_{\rm m}}(0,55\sqrt{L_{\rm R}}+1,5)\geq 3,0\,\omega$	$\omega\sqrt{k_{\rm m}}(0,55\sqrt{L_{\rm R}}+1,5)\geq 3,0\,\omega$	$\omega\sqrt{k_{\rm m}}(0,55\sqrt{L_{\rm R}}+1,5)\geq 3,0\,\omega$
Deckhouse aft	$\omega\sqrt{k_{\rm m}}(0,25\sqrt{L_{\rm R}}+0,7)\geq 2,5\,\omega$	$\omega\sqrt{k_{\rm m}}(0,25\sqrt{L_{\rm R}}+0,7)\geq 2,5\,\omega$	$\omega\sqrt{k_{\rm m}}(0,25\sqrt{L_{\rm R}}+0,7)\geq 2,5\,\omega$
Pillars Wall thickness of tubular pillars	$\omega\sqrt{k_{\rm m}}0,07d_{\rm p}$	$\omega\sqrt{k_{\rm m}}0,07d_{\rm p}$	$\omega\sqrt{k_{\rm m}}0,07d_{\rm p}$
Wall thickness of rectangular pillars	$\omega\sqrt{k_{\rm m}}0,07b_{\rm p}$	$\omega\sqrt{k_{\rm m}}0,07b_{\rm p}$	$\omega\sqrt{k_{\rm m}}0,07b_{\rm p}$
Symbols			

ω = service type factor as determined from *Table 4.2.2 Service type correction factors (ω)*

k_m = $385/(\sigma_A + \sigma_u)$

σ_A = specified minimum yield stress or 0,2% proof stress of the alloy in unwelded condition, in N/mm^2

σ_u = specified minimum ultimate tensile strength of the alloy in unwelded condition, in N/mm^2

b_p = minimum breadth of cross section of hollow rectangular pillar, in mm

d_p = outside diameter of tubular pillar, in mm

L_R = as defined in *Pt 7, Ch 4, 1.5 Symbols and definitions 1.5.1*

$\varphi_p = \dfrac{0,5\,s}{(105 + L_R)}$ but is not taken greater than 1 and not less than 0,5

$\varphi_s = \dfrac{0,6\,s}{(105 + L_R)}$ but is not taken greater than 1 and not less than 0,5

s = stiffener spacing, in mm

Note 1. Lower thickness may be acceptable depending on the location, loading and provision of protective sheathing as appropriate.

Table 4.2.2 Service type correction factors (ω)

Service type notation	ω
Cargo	1,1
Passenger	1,0
Patrol	1,0
Pilot	1,1
Yacht	1,0
Workboat MFV	1,2

■ *Section 3*
Shell envelope plating

3.1 General

3.1.1 Unless otherwise specified within this Section, the scantlings and arrangements for shell envelope plating are to be determined in accordance with the procedures described in, or as required by, *Pt 7, Ch 4, 3.3 Bottom outboard* for mono-hull craft using the pressures from *Pt 5 Design and Load Criteria* appropriate to multi-hulls.

3.1.2 The thickness of the shell envelope plating is in no case to be less than the appropriate minimum requirement given in *Pt 7, Ch 4, 2 Minimum thickness requirements*.

3.2 Keel plates

3.2.1 The thickness of keel plating is not to be less than the adjacent bottom shell plating and is to be sufficient to withstand the forces imposed by dry-docking the craft.

3.3 Bottom outboard

3.3.1 The thickness of the bottom outboard plating is to be determined from the general plating equation given in *Pt 7, Ch 3, 1.16 Plating general* using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

3.3.2 For all craft types, the minimum bottom outboard shell thickness requirement given in *Pt 7, Ch 4, 2 Minimum thickness requirements* is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

3.4 Bottom inboard

3.4.1 The thickness of the bottom inboard plating is to be determined from the general plating equation given in *Pt 7, Ch 3, 1.16 Plating general* using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

3.4.2 For all craft types, the minimum bottom inboard shell thickness requirement given in *Pt 7, Ch 4, 2 Minimum thickness requirements* is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

3.5 Side outboard

3.5.1 The thickness of the side outboard plating is to be determined from the general plating equation given in *Pt 7, Ch 3, 1.16 Plating general* using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

3.6 Side inboard

3.6.1 The thickness of the side inboard plating is to be determined from the general plating equation given in *Pt 7, Ch 3, 1.16 Plating general* using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

3.7 Wet-deck

3.7.1 The thickness of the wet-deck plating is to be determined from the general plating equation given in *Pt 7, Ch 3, 1.16 Plating general* using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

3.7.2 Additionally, the thickness of the wet-deck plating is in no case to be less than the thickness of the side inboard shell plating determined from *Pt 7, Ch 4, 3.6 Side inboard*.

3.7.3 The wet-deck plating on the underside of the cross-deck structure may require to be additionally protected, particularly where the air gap is small and there is a high risk of localised impact due to collision with floating debris, ice, etc. in the service area. In such cases the sheathing requirements given in *Pt 7, Ch 3, 2.4 Sheathing* are to be complied with.

3.8 Transom

3.8.1 The scantlings and arrangements of the stern or transom are to be not less than that required for the adjacent bottom inboard or side outboard structure as appropriate. Where water jet or sterndrive units are fitted, the scantlings of the plating in way of the nozzles and connections will be specially considered.

3.9 Haunch reinforcement (SWATH)

3.9.1 For craft above 40 m in Rule length, L_R, the stresses in the haunch area are to be derived using a two dimensional fine mesh finite element analysis. The model is to extend horizontally into the box structure and vertically into the strut structure. All discontinuities and cut-outs are to be modelled in order to determine shear stresses at critical locations and stresses for the determination of fatigue strength.

3.9.2 Due consideration is to be given to shear lag when determining the effective breadth of the attached plating.

3.10 Lower hull (SWATH)

3.10.1 Where the lower hull structure incorporates ring frames and attached shell plating fitted between bulkheads or diaphragms, the thickness of the lower hull shell plating may be derived from an established method for shell analysis or recognised standard for pressure vessels using the design pressure loading from *Pt 5, Ch 4, 3.1 Hull structures*. Other loads considered significant for the scantling determination are to be taken into account. Modes of failure to be considered are buckling,

frame collapse, inter-frame shell collapse and overall frame shell collapse between bulkheads. A copy of the direct calculations is to be submitted for consideration.

3.11 Novel features

3.11.1 Where the Rules do not specifically define the requirements for plating elements with novel features then the scantlings and arrangements are to be determined by direct calculations. Such calculations are to be carried out on the basis of the Rules, Recognised Standards and good practice, and are to be submitted for consideration.

■ *Section 4* Shell envelope framing

4.1 General

4.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for shell envelope framing are to be determined in accordance with the procedures described in, or as required by, *Pt 7, Ch 3, 3 Shell envelope plating* for mono-hull craft using the pressures from *Pt 5 Design and Load Criteria* appropriate to multi-hulls.

4.1.2 The requirements in this Section apply to longitudinally and transversely framed shell envelopes.

4.2 Bottom outboard longitudinal stiffeners

4.2.1 Bottom outboard longitudinal stiffeners are to be supported by transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.2.2 Bottom outboard longitudinals are to be continuous through the supporting structures.

4.2.3 Where it is impracticable to comply with the requirements of *Pt 7, Ch 4, 4.2 Bottom outboard longitudinal stiffeners 4.2.2*, or where it is proposed to terminate the bottom outboard longitudinals in way of the transom, bulkheads or integral tank boundaries, all longitudinals are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets.

4.2.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 7, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* in Chapter 3 for the load model (b).

4.3 Bottom outboard longitudinal primary stiffeners

4.3.1 Bottom outboard longitudinal primary stiffeners are to be supported by deep transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 4 m apart.

4.3.2 Bottom outboard longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

4.3.3 Where it is impracticable to comply with the requirements of *Pt 7, Ch 4, 4.3 Bottom outboard longitudinal primary stiffeners 4.3.2*, or where it is proposed to terminate the stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be `soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.3.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 7, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* for the load model (a).

4.4 Bottom outboard transverse stiffeners

4.4.1 Bottom outboard transverse stiffeners are defined as local stiffening members which support the bottom shell and which may be continuous or intercostal.

4.4.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 7, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* in Chapter 3 for the load model (b).

4.5 Bottom outboard transverse frames

4.5.1 Bottom outboard transverse frames are defined as stiffening members which support the bottom shell. They are to be effectively continuous and bracketed at their end connections to side frames and bottom floors as appropriate.

4.5.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 7, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* in Chapter 3 for the load model (a).

4.6 Bottom outboard transverse web frames

4.6.1 Bottom outboard transverse web frames are defined as primary stiffening members which support bottom shell longitudinals. They are to be continuous and substantially bracketed at their end connections to side web frames and bottom floors.

4.6.2 Where it is impracticable to comply with the requirements of *Pt 7, Ch 4, 4.6 Bottom outboard transverse web frames 4.6.1*, or where it is proposed to terminate the web frames in way of bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets. All brackets are to be `soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.6.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 7, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* in Chapter 3 for the load model (a).

4.7 Bottom inboard longitudinal stiffeners

4.7.1 The scantlings and arrangements for bottom inboard longitudinal stiffeners are to be determined in accordance with the procedures described in *Pt 7, Ch 4, 4.2 Bottom outboard longitudinal stiffeners* using the bottom inboard stiffening member design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

4.8 Bottom inboard longitudinal primary stiffeners

4.8.1 The scantlings and arrangements for bottom inboard longitudinal primary stiffeners are to be determined in accordance with the procedures described in *Pt 7, Ch 4, 4.3 Bottom outboard longitudinal primary stiffeners* using the bottom inboard stiffening member design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

4.9 Bottom inboard transverse stiffeners

4.9.1 The scantlings and arrangements for bottom inboard transverse stiffeners are to be determined in accordance with the procedures described in *Pt 7, Ch 4, 4.4 Bottom outboard transverse stiffeners* using the bottom inboard stiffening member design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

4.10 Bottom inboard transverse frames

4.10.1 The scantlings and arrangements for bottom inboard transverse frames are to be determined in accordance with the procedures described in *Pt 7, Ch 4, 4.5 Bottom outboard transverse frames* using the bottom inboard stiffening member design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

4.11 Bottom inboard transverse web frames

4.11.1 The scantlings and arrangements for bottom inboard transverse frames are to be determined in accordance with the procedures described in *Pt 7, Ch 4, 4.6 Bottom outboard transverse web frames* using the bottom inboard stiffening design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

4.12 Side outboard longitudinal stiffeners

4.12.1 The side outboard longitudinal stiffeners are to be supported by transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.12.2 Side outboard longitudinals are to be continuous through the supporting structures.

4.12.3 Where it is impracticable to comply with the requirements of *Pt 7, Ch 4, 4.12 Side outboard longitudinal stiffeners 4.12.2*, or where it is proposed to terminate the side outboard longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.12.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 7, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* in Chapter 3 for the load model (b).

4.13 Side outboard longitudinal primary stiffeners

4.13.1 Side outboard longitudinal primary stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 4 m apart.

4.13.2 Side outboard longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

4.13.3 Where it is impracticable to comply with the requirements of *Pt 7, Ch 4, 4.13 Side outboard longitudinal primary stiffeners 4.13.2*, or where it is proposed to terminate the side outboard longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets. All brackets are to be `soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.13.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 7, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* in Chapter 3 for the load model (a).

4.14 Side outboard transverse stiffeners

4.14.1 Side outboard transverse stiffeners are defined as local stiffening members supporting the side shell and may be continuous or intercostal.

4.14.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 7, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* in Chapter 3 for the load model (b).

4.15 Side outboard transverse frames

4.15.1 Side outboard transverse frames are defined as stiffening members supporting the side shell and spanning continuously between bottom floors/frames and decks. They are to be effectively constrained against rotation at their end connections.

4.15.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 7, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* in Chapter 3 for the load model (a).

4.16 Side outboard transverse web frames

4.16.1 Side outboard transverse web frames are defined as primary stiffening members which support side shell longitudinals. They are to be continuous and substantially bracketed at their head and heel connections to deck beams and bottom web frames respectively.

4.16.2 Where it is impracticable to comply with the requirements of *Pt 7, Ch 4, 4.16 Side outboard transverse web frames 4.16.1*, or where it is proposed to terminate the side outboard longitudinals in way of bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be `soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.16.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 7, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* in Chapter 3 for the load model (a).

4.17 Side inboard longitudinal stiffeners

4.17.1 The scantlings and arrangements for side inboard longitudinal stiffeners are to be determined in accordance with the procedures described in *Pt 7, Ch 4, 4.12 Side outboard longitudinal stiffeners* using the side inboard design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

4.18 Side inboard longitudinal primary stiffeners

4.18.1 The scantlings and arrangements for side inboard longitudinal primary stiffeners are to be determined in accordance with the procedures described in *Pt 7, Ch 4, 4.13 Side outboard longitudinal primary stiffeners* using the side inboard design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

4.19 Side inboard transverse stiffeners

4.19.1 The scantlings and arrangements for side inboard transverse stiffeners are to be determined in accordance with the procedures described in *Pt 7, Ch 4, 4.14 Side outboard transverse stiffeners* using the side inboard design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

4.20 Side inboard transverse frames

4.20.1 The scantlings and arrangements for side inboard transverse frames are to be determined in accordance with the procedures described in *Pt 7, Ch 4, 4.15 Side outboard transverse frames* using the side inboard design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

4.21 Side inboard transverse web frames

4.21.1 The scantlings and arrangements for side inboard transverse web frames are to be determined in accordance with the procedures described in *Pt 7, Ch 4, 4.16 Side outboard transverse web frames* using the side inboard design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

4.22 Wet-deck longitudinal stiffeners

4.22.1 The wet-deck longitudinal stiffeners are to be supported by transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.22.2 Wet-deck longitudinals are to be continuous through the supporting structures.

4.22.3 Where it is impracticable to comply with the requirements of *Pt 7, Ch 4, 4.22 Wet-deck longitudinal stiffeners 4.22.2*, or where it is proposed to terminate the wet-deck longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.22.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 7, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures*

for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* in Chapter 3 for the load model (b).

4.22.5 In no case are the scantlings and arrangements for the wet-deck longitudinal stiffeners to be taken as less than those required for the side inboard longitudinal stiffeners detailed in *Pt 7, Ch 4, 4.17 Side inboard longitudinal stiffeners*.

4.23 Wet-deck longitudinal primary stiffeners

4.23.1 Wet-deck longitudinal primary stiffeners are to be supported by transverse web frames, bulkheads, or other primary structure, generally spaced not more than 4 m apart.

4.23.2 Wet-deck longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

4.23.3 Where it is impracticable to comply with the requirements of *Pt 7, Ch 4, 4.23 Wet-deck longitudinal primary stiffeners 4.23.2*, or where it is proposed to terminate the wet-deck longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.23.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 7, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* in Chapter 3 for the load model (a).

4.23.5 In no case are the scantlings and arrangements for the wet-deck longitudinal primary stiffeners to be taken as less than those required for the side inboard longitudinal primary stiffeners detailed in *Pt 7, Ch 4, 4.18 Side inboard longitudinal primary stiffeners*.

4.23.6 Additionally the requirements of *Pt 7, Ch 6 Hull Girder Strength* relating to global strength are to be complied with.

4.24 Wet-deck transverse stiffeners

4.24.1 Wet-deck transverse stiffeners are defined as local stiffening members supporting the wet-deck and may be continuous or intercostal.

4.24.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 7, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* in Chapter 3 for the load model (b).

4.24.3 In no case are the scantlings and arrangements for the `wet-deck' transverse stiffeners to be taken as less than those required for the side inboard transverse stiffeners detailed in *Pt 7, Ch 4, 4.19 Side inboard transverse stiffeners*.

4.25 Wet-deck transverse frames

4.25.1 Wet-deck transverse frames are defined as stiffening members which support the wet-deck. They are to be effectively continuous and bracketed at their end connections to side frames.

4.25.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 7, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* in Chapter 3 for the load model (a).

4.25.3 In no case are the scantlings and arrangements for the wet-deck transverse frames to be taken as less than those required for the side inboard transverse frames detailed in *Pt 7, Ch 4, 4.20 Side inboard transverse frames*.

4.26 Wet-deck transverse web frames

4.26.1 Wet-deck transverse web frames are defined as primary stiffening members which support wet-deck longitudinals. They are to be continuous and substantially bracketed at their end connections to side transverse web frames.

4.26.2 Where it is impracticable to comply with the requirements of *Pt 7, Ch 4, 4.26 Wet-deck transverse web frames 4.26.1*, or where it is proposed to terminate the wet-deck longitudinals in way of the bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure

accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.26.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in *Pt 7, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* in Chapter 3 for the load model (a).

4.26.4 In no case are the scantlings and arrangements for the wet-deck transverse web frames to be taken as less than those required for the side inboard transverse web frames detailed in *Pt 7, Ch 4, 4.21 Side inboard transverse web frames*.

4.26.5 Primary transverse web frames that link the strength deck to the wet-deck structure and which carry the transverse global loading are additionally to comply with *Pt 7, Ch 6, 3.4 Torsional strength*.

4.26.6 Particular care is to be taken to ensure that the continuity of transverse structural strength is maintained. All primary transverse members are to be continuous through the inboard side structure and integrated into transverse bulkheads or other primary structure within each hull (*see Figure 4.4.1 End connection details, wet-deck structure*). In the case of trimaran type craft the primary transverse members are to be continuous through the centre hull. Additionally the side inboard shell plating in way of the intersection is to be increased locally by not less than 50 per cent.

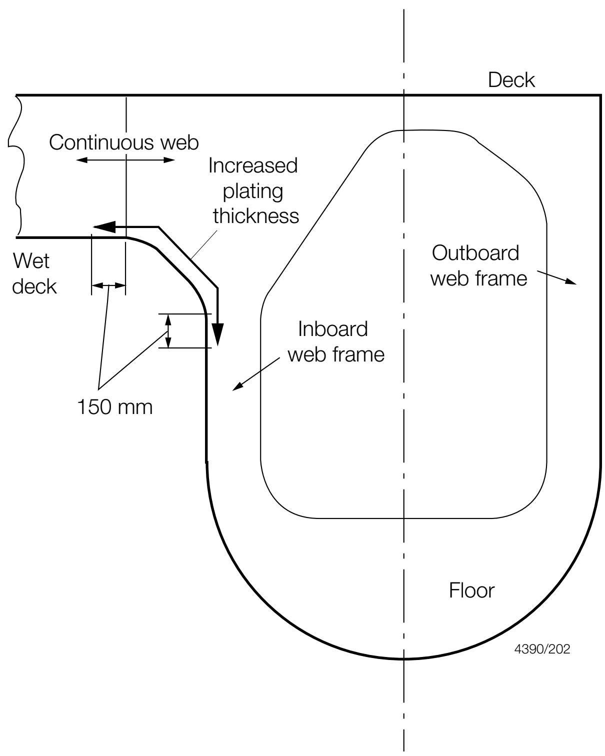


Figure 4.4.1 End connection details, wet-deck structure

4.27 Lower hull (SWATH)

4.27.1 Where the lower hull structure incorporates ring frames and attached shell plating fitted between bulkheads or diaphragms, the scantlings of the lower hull shell stiffening may be derived from an established method for stiffening analysis or recognised standard for pressure vessels using the design loading from *Pt 5, Ch 4, 3.1 Hull structures*. Modes of failure to be considered are buckling, frame collapse, inter frame shell collapse and overall frame shell collapse between bulkheads. A copy of the direct calculations is to be submitted for consideration.

4.28 Scantlings of end brackets

4.28.1 The scantlings of end brackets in way of transverse web frames/crossdeck primary structure which carry transverse global loading, are to be as large as practicable and be additionally reinforced as necessary. The webs of deep brackets are to be stiffened as necessary to resist buckling, *see also Pt 7, Ch 6, 3.5 Strength of cross-deck structures*.

■ *Section 5* Single bottom structure and appendages

5.1 General

5.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for single bottom structure and appendages are to be determined in accordance with the procedures described in, or as required by, *Pt 7, Ch 3, 5 Single bottom structure and appendages* for mono-hull craft using the pressures from *Pt 5 Design and Load Criteria* appropriate to multi-hulls.

5.1.2 The thickness of single bottom structural members is in no case to be less than the appropriate minimum requirement given in *Pt 7, Ch 4, 2 Minimum thickness requirements*.

5.1.3 Where alternatives to the requirements of *Pt 7, Ch 4, 5.1 General 5.1.1* and *Pt 7, Ch 4, 5.1 General 5.1.2* are proposed, they will be specially considered, provided that calculations are submitted to demonstrate that the proposed alternatives have adequate strength, rigidity and stability to resist all anticipated design loadings.

5.2 Keel

5.2.1 The scantlings and arrangements of plate keels are to be in accordance with *Pt 7, Ch 4, 3.2 Keel plates*.

5.2.2 Where a bar keel is fitted, the scantlings are to be sufficient to withstand the forces imposed by dry-docking the craft.

5.3 Centre girder

5.3.1 Centreline girders are generally to be fitted throughout the length of each hull for dry-docking or where the breadth of floors at the upper edge is greater than 1,5 m. They are generally to be fitted in association with transverse frames or transverse web frames supporting longitudinals.

5.3.2 Centreline girders may be formed with intercostal or continuous plate webs. In all cases the face flat is to be continuous. Where girder webs are intercostal, additional bracketing and local reinforcement are to be provided to maintain the continuity of structural strength.

5.3.3 The geometric section properties of the girder webs are to be in accordance with *Pt 7, Ch 3, 1.18 Geometric properties and proportions of stiffener sections*.

5.3.4 The face flat thickness is to be not less than the thickness of the web. The ratio of the width to thickness of the face flat is to be not less than eight but is not to exceed 16.

5.3.5 Centreline girders are to comply with the requirements of *Pt 7, Ch 4, 4.8 Bottom inboard longitudinal primary stiffeners*. The girder is to have adequate resistance to buckling and in some cases web stiffeners may be required.

5.4 Side girders

5.4.1 Where the floor breadth at the upper edge exceeds 4,0 m, side girders are to be fitted at each side of the centreline girder such that the spacing between the side and centreline girders or between the side girders themselves is not greater than 2 m. Side girders where fitted are to extend as far forward and aft as practicable and are, in general, to be scarfed into the bottom structure forward and aft of the support at which they terminate, i.e. terminate in way of bulkheads, deep floors or other primary transverse structure.

5.4.2 The geometric section properties of the girders are to be in accordance with *Pt 7, Ch 3, 1.18 Geometric properties and proportions of stiffener sections*. The girder webs and face flats are to have adequate resistance to buckling.

5.4.3 The face flat thickness is to be not less than the thickness of the web. The ratio of the width to thickness of the face flat is to be not less than eight but is not to exceed 16.

5.4.4 Side girders are to comply with the requirements of *Pt 7, Ch 4, 4.8 Bottom inboard longitudinal primary stiffeners*. The girders are to have adequate resistance to buckling and web stiffeners may be required.

5.4.5 Watertight side girders, and side girders forming the boundaries of tank spaces, are to comply with the requirements for watertight bulkheads and deeptanks as detailed in *Pt 7, Ch 3, 7.2 Watertight bulkhead plating* and *Pt 7, Ch 3, 7.4 Deep tank plating* respectively.

5.4.6 In the engine room, additional side girders are generally to be fitted in way of main machinery seatings. Where fitted, they are to be integrated into the structure of the craft and extended forward and aft as far as practicable.

5.5 Floors general

5.5.1 In transversely framed craft, floors are generally to be fitted at every frame and underneath each bulkhead.

5.5.2 In longitudinally framed craft, floors are, in general, to be fitted at every transverse web frame and bulkhead, and generally at a spacing not exceeding 2 m. Additional transverse floors or webs are to be fitted at half web frame spacing in way of engine seatings and thrust bearings, pillars, skegs, ballast/bilge keels and the bottom of the craft in the forefoot region.

5.5.3 The overall depth of floors at the centreline is not to be taken as less than:

$$d_f = 6{,}2L_R + 50\text{mm}$$

Where L_R is defined in *Pt 7, Ch 4, 1.5 Symbols and definitions 1.5.1*

5.5.4 The geometric section properties of the girders are to be in accordance with *Pt 7, Ch 3, 1.18 Geometric properties and proportions of stiffener sections*. The girder webs and face flats are to have adequate resistance to buckling.

5.5.5 The face flat thickness is to be not less than the thickness of the web. The ratio of the width to thickness of the face flat is to be not less than eight but is not to exceed 16.

5.5.6 Bottom inboard transverse web frames are to comply with the requirements of *Pt 7, Ch 4, 4.11 Bottom inboard transverse web frames*. The floors are to have adequate resistance to buckling and web stiffeners may be required.

5.5.7 Floors are in general to be continuous from side to side and the tops of floors are, in general, to be level from side to side. For craft having considerable rise of floor the depth of the floor plate may require to be increased to maintain the required section modulus.

5.5.8 The floors are to provide efficient support to the stern tube(s) where applicable.

5.5.9 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deeptanks as detailed in *Pt 7, Ch 3, 7.2 Watertight bulkhead plating* and *Pt 7, Ch 3, 7.4 Deep tank plating* respectively.

5.6 Floors in machinery space

5.6.1 Floors of increased thickness may be required in way of machinery spaces.

5.6.2 The depth and mechanical strength properties of floors between engine or gearbox girders is to be not less than that required to maintain continuity of structural integrity. The face flat area and web thickness of such reduced height floors are to be increased appropriately in order to maintain the continuity of structural strength, *see also Pt 7, Ch 3, 4.12 Grouped frames*.

5.7 Forefoot and stem

5.7.1 The thickness of plate stems at the waterline is to comply with the requirements for plate keels as given in *Pt 7, Ch 4, 3.2 Keel plates*.

5.7.2 The forefoot and stem are to be additionally reinforced with floors.

5.7.3 The cross-sectional area of bar stems, A_{bs}, is not to be taken as less than :

$$A_{bs} = 1{,}1 k_a L_R \text{ cm}^2$$

where

k_a and L_R are as defined in *Pt 7, Ch 4, 1.5 Symbols and definitions 1.5.1*.

Section 6
Double bottom structure

6.1 General

6.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for the double bottom structure are to be determined in accordance with the procedures described in, or as required by, *Pt 7, Ch 3, 6 Double bottom structure* for mono-hull craft using the pressures from *Pt 5 Design and Load Criteria* appropriate to multi-hulls.

6.1.2 The thickness of double bottom structural members is in no case to be less than the appropriate minimum requirement given in *Pt 7, Ch 4, 2 Minimum thickness requirements*.

6.1.3 Where alternatives to the requirements of *Pt 7, Ch 4, 6.1 General 6.1.1* and *Pt 7, Ch 4, 6.1 General 6.1.2* are proposed, they may be specially considered provided that calculations are submitted to demonstrate that the proposed alternatives have adequate strength, rigidity and stability to resist all anticipated design loadings.

6.2 Keel

6.2.1 The scantlings of plate and bar keels are to comply with the requirements of *Pt 7, Ch 4, 5.2 Keel*.

6.3 Centreline girder

6.3.1 Centreline girder is to be fitted throughout the length of the craft. The web thickness, t_{w}, is to be not less than that required by:

$$t_{w} = \sqrt{k_{a}}\left(0,082\ L_{R} + 4,1\right)\ mm within\ 0,4 L amidships$$
$$= \sqrt{k_{a}}\left(0,082\ L_{R} + 2,7\right)\ mm at ends$$

where

k_{a} and L_{R} are as defined in *Pt 7, Ch 4, 1.5 Symbols and definitions*.

6.3.2 The geometric properties of the girder section are to be in accordance with *Pt 7, Ch 3, 1.18 Geometric properties and proportions of stiffener sections*.

6.3.3 The overall web depth, d_{w}, of the centre girder is to be taken as not less than 630 mm and is to be sufficient to give adequate access to all parts of the double bottom.

6.3.4 Additionally, the requirements of *Pt 7, Ch 4, 4.8 Bottom inboard longitudinal primary stiffeners* for bottom inboard longitudinal primary stiffeners are to be complied with.

6.4 Side girders

6.4.1 Where the floor breadth does not exceed 4,0 m, side girders are not required. Vertical stiffeners are to be fitted to the floors on each side, the number and positions of these stiffeners being dependent on the arrangement of the double bottom structure.

6.4.2 Where the breadth of floor is greater than 4,0 m, additional side girders having the same thickness as the floors are to be fitted. The number of side girders is to be such that the distance between the side girders and centre girder and margin plate, or between the side girders themselves, does not exceed 2,0 m.

6.4.3 Side girders, where fitted, are to extend as far forward and aft as practicable and are in general to be scarfed into the bottom structure forward and aft of the supporting bulkheads, deep floors or other primary transverse structure.

6.4.4 Where additional side girders are fitted in way of main machinery seatings, they are to be integrated into the structure of the craft and extended forward and aft as far as practicable.

6.4.5 Under the main engine, girders extending from the bottom shell to the top plate of the engine seating are to be fitted. The height of the girders is to be not less than the height of the floor. Engine holding-down bolts are to be arranged as near as practicable to the girders and floors. Where this cannot be achieved, bracket floors and/or hanging brackets are to be fitted.

6.4.6 The geometric properties of the girder section are to be in accordance with *Pt 7, Ch 3, 1.18 Geometric properties and proportions of stiffener sections*.

6.4.7 Additionally, the requirements of *Pt 7, Ch 4, 4.8 Bottom inboard longitudinal primary stiffeners* for bottom inboard longitudinal primary stiffeners are to be complied with.

6.5 Plate floors

6.5.1 The web thickness, t_{w}, of non-watertight plate floor is to be not less than:

$$t = \sqrt{k_{\mathrm{a}}}\left(0,041\ L_{\mathrm{R}} + 4,8\right)\ \mathrm{mm}$$

where k_{a} and L_{R} are as defined in *Pt 7, Ch 4, 1.5 Symbols and definitions*.

6.5.2 The geometric properties of the floor section are to be in accordance with *Pt 7, Ch 3, 1.18 Geometric properties and proportions of stiffener sections*.

6.5.3 Additionally, the requirements of *Pt 7, Ch 4, 4.11 Bottom inboard transverse web frames* for bottom inboard transverse web frames are to be complied with.

6.5.4 Plate floors are, in general, to be continuous between the centre girder and the margin plate.

6.5.5 In longitudinally framed craft, plate floors are to be fitted in the following positions:

(a) At every half frame in way of the main engines, thrust bearings, and bottom of the craft forward.
(b) Outboard of the engine seatings, at every frame within the engine room.
(c) Underneath pillars and bulkheads.
(d) Outside of the engine room at a spacing not exceeding 2,0 m.

6.5.6 Vertical flat bar stiffeners are to be fitted to all plate floors at each longitudinal. Each stiffener is to have a depth of not less than $10t_{\mathrm{w}}$ and a thickness of not less than t_{w}, where t_{w} is thickness of the plate floor as calculated in *Pt 7, Ch 4, 6.5 Plate floors 6.5.1*.

6.5.7 In transversely framed craft, plate floors are to be fitted at every frame in the engineroom, under bulkheads, in way of change in depth of double bottom and elsewhere at a spacing not exceeding 2,0 m.

6.6 Additional requirements for watertight floors

6.6.1 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deeptanks as detailed in *Pt 7, Ch 3, 7.2 Watertight bulkhead plating* or *Pt 7, Ch 3, 7.4 Deep tank plating* respectively.

■ *Section 7*
Bulkheads and deep tanks

7.1 General

7.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for bulkheads and deep tanks are to be determined in accordance with the procedures described in, or as required by *Pt 7, Ch 3, 7 Bulkheads and deep tanks* for mono-hull craft using the pressures from *Pt 5 Design and Load Criteria* appropriate to multi-hulls.

7.2 Longitudinal bulkheads within the cross-deck structure

7.2.1 Longitudinal bulkheads are to be fitted within the cross-deck structure to prevent cross flooding and the spread of flame and smoke. The minimum number of such bulkheads is to be:

- one for catamarans of Rule length, L_{R}, less than or equal to 24 m;
- two for catamarans of Rule length, L_{R}, greater than 24 m; and
- four for trimarans.

Quadrimarans and other craft of novel configuration will be specially considered.

7.2.2 The scantlings and arrangements for cross-deck longitudinal bulkheads are to be determined in accordance with the procedures described in *Pt 7, Ch 3, 7.2 Watertight bulkhead plating* and *Pt 7, Ch 3, 7.3 Watertight bulkhead stiffening* for bulkheads in mono-hull craft.

7.2.3 In addition the requirements of *Pt 7, Ch 4, 7.4 Additional strength required for global loadings* with regard to global strength are to be complied with.

7.3 Transverse bulkheads within the cross-deck structure

7.3.1 The scantlings of cross-deck transverse bulkheads are to be determined in accordance with the procedures described in *Pt 7, Ch 3, 7.2 Watertight bulkhead plating* and *Pt 7, Ch 3, 7.3 Watertight bulkhead stiffening* for bulkheads in mono-hull craft.

7.3.2 In addition the requirements of *Pt 7, Ch 4, 7.4 Additional strength required for global loadings* in respect of global strength are to be complied with.

7.4 Additional strength required for global loadings

7.4.1 Where transverse bulkheads or deep tank bulkheads within the cross-deck structure are to assist in resisting torsional or bending loads between the hulls, then the watertight/deep tank bulkheads may be required to be additionally stiffened and the plating or skin thicknesses may require to be increased. For hull girder strength requirements, *see Pt 7, Ch 6, 3 Additional hull girder strength requirements for multi-hull craft*.

7.4.2 Longitudinal bulkheads within the cross-deck structure that are to assist in maintaining the longitudinal strength of the vessel are to satisfy both bulkhead/deep tank and longitudinal strength requirements.This may require additional stiffening and increase in plate thickness requirements. For hull girder strength requirements *see Pt 7, Ch 6, 3 Additional hull girder strength requirements for multi-hull craft*.

7.4.3 Where longitudinal or transverse cross-deck bulkheads/deep tanks are to carry global loads, detailed calculations are to be submitted.

7.4.4 For longitudinal or transverse cross-deck members carrying global loads, consideration is to be given to stiffener arrangement, alignment, and continuity in order to maximise the rigidity and stiffness of the structure, in resisting the torsional/ bending loads. Discontinuity of structural bulkheads is to be avoided.

7.5 Access

7.5.1 Access through the cross-deck structure may be permitted, provided that the global strength requirements are satisfied. Cut outs through the bulkhead are not to exceed 50 per cent of its depth, *see also Pt 7, Ch 3, 7.18 Access*.

7.5.2 Where the cross-deck structure acts as a watertight bulkhead pipe or cable runs through, the watertight bulkheads are to be fitted with suitable watertight glands.

7.6 Local reinforcement

7.6.1 Bulkheads forming the cross-deck structure are to be suitably strengthened, if necessary, in way of deck girders and where subjected to concentrated loads.

7.7 Integral/deep tanks within cross-deck structure

7.7.1 Where the cross-deck structure forms the boundaries of deep tanks, the scantlings of these boundaries are to satisfy both deep tank and global strength requirements. For general and structural requirements for deep tanks, *see Pt 7, Ch 3, 7 Bulkheads and deep tanks*. For global considerations of strength *see Pt 7, Ch 6, 3 Additional hull girder strength requirements for multi-hull craft*.

■ *Section 8*
Deck structures

8.1 General

8.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for deck structures are to be determined in accordance with the procedures described in, or as required by, *Pt 7, Ch 3, 8 Deck structures* for mono-hull craft using the pressures from *Pt 5 Design and Load Criteria* appropriate to multi-hulls.

8.2 Arrangements

8.2.1 Design loads to be applied for cross-deck scantling calculations are transverse vertical bending moment and shear force, twin hull torsional connecting moment, external pressure load and appropriate internal loads as defined in *Pt 5 Design and Load Criteria*.

8.2.2 For craft up to 50 m in Rule length, L_R, where the cross-deck is formed by transverse primary stiffeners or bulkheads, and subjected to global transverse loads in accordance with *Pt 7, Ch 4, 8.2 Arrangements 8.2.1* the scantling requirements to satisfy the global loading condition are given in *Pt 7, Ch 6, 3.5 Strength of cross-deck structures*.

8.2.3 Superstructures fitted on the cross-deck structures, on craft up to 50 m in Rule length, L_R, will, in general, be considered as non-load carrying and are not to be included in the strength of the cross-deck. For designs where the superstructure is designed to absorb global loads, the requirements are given in *Pt 7, Ch 6, 3.2 Hull longitudinal bending strength*.

8.2.4 For craft more than 50 m in Rule length, L_R, global analysis is required to determine the response of the deck and superstructure as a system. Deck scantlings may then be derived for compliance with the requirements of *Pt 7, Ch 6, 3 Additional hull girder strength requirements for multi-hull craft*.

8.3 Cross-deck plating

8.3.1 The thickness of the cross-deck plating is to be determined from the general plating equation given in *Pt 7, Ch 3, 1.16 Plating general* using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

8.3.2 The thickness of the cross-deck plating is in no case to be less than the appropriate minimum requirement given in *Pt 7, Ch 4, 2 Minimum thickness requirements*.

8.3.3 The scantlings of watertight cockpits are to be of equivalent strength to those of the strength/weather deck, *see also Pt 4 Additional Requirements for Yachts*.

8.3.4 It is recommended that the working areas of the weather deck have an anti-slip surface.

8.3.5 Where decks are sheathed with wood or other materials, details of the method of attachment are to be submitted, *see also Pt 7, Ch 3, 2.4 Sheathing*.

8.4 Cross-deck stiffening

8.4.1 The Rule requirements for section modulus, inertia and web area for the cross-deck primary stiffeners are to be determined from the general equations given in *Pt 7, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* in Chapter 3 for the load model (a).

8.4.2 The Rule requirements for section modulus, inertia and web area of the strength/weather deck secondary stiffening are to be determined from the general equations given in *Pt 7, Ch 3, 1.17 Stiffening general*, using the design pressures from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in *Table 3.1.1 Section modulus, inertia and web area coefficients* in Chapter 3 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.4.3 The geometric properties of stiffener sections are to be in accordance with *Pt 7, Ch 3, 1.18 Geometric properties and proportions of stiffener sections*.

8.4.4 For cases where there may be excessive rotations or deflections at supports or where the lateral pressure distribution is non-uniform, the above scantlings may require increasing appropriately.

8.4.5 Where stiffeners are subject to concentrated loads such as pillars, the concentrated loads are to be superimposed on the lateral pressure and strength calculations carried out to demonstrate compliance with the deflection and stress criteria given in *Pt 7, Ch 7, 2 Deflection control* and *Pt 7, Ch 7, 3 Stress control*.

8.4.6 Where stiffening members support plating of the extruded plank type, or the floating frame system is used, the plating is not to be included in the scantling derivation of the supporting structure.

8.4.7 Openings in the cross-deck for hatches etc. are to comply with the requirements of *Pt 7, Ch 3, 8.11 Deck openings*.

8.5 Novel features

8.5.1 Where the cross-deck structure is of unusual design, form or proportions, the scantlings are to be determined by direct calculation and a copy is to be submitted for consideration.

■ *Section 9* Superstructures, deckhouses, pillars and bulwarks

9.1 General

9.1.1 The scantlings and arrangements for superstructures, deckhouses and bulwarks are to be determined in accordance with the procedures described in, or as required by, *Pt 7, Ch 3, 9 Superstructures, deckhouses and bulwarks* for mono-hull craft.

9.1.2 The scantlings and arrangements for pillars and pillar bulkheads are to be determined in accordance with the procedures described in, or as required by, *Pt 7, Ch 3, 10 Pillars and pillar bulkheads* for mono-hull craft.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull and multi-hull craft of aluminium construction as defined in *Ch 1, 1 Background*.

1.2 Symbols and definitions

1.2.1 The symbols and definitions used in this Chapter are defined below and in the appropriate Section:

s = stiffener spacing, in mm

k_a = alloy factor

= $125/\sigma_a$

σ_a = 0,2 per cent proof stress of the alloy in the welded condition, in N/mm^2.

■ *Section 2* Special features

2.1 Water jet propulsion systems - Construction

2.1.1 The requirements for the construction and installation of water jet units apply irrespective of rated power.

2.1.2 Water jet ducts may be fabricated as an integral part of the hull structure, or as a bolted-in unit. In either case, detailed plans indicating dimensions, scantlings and materials of construction of the following are to be submitted in triplicate:

(a) Arrangement of the system including intended method of attachment to the hull and building-in, geometry of tunnel, shell opening, method of stiffening, reinforcement, etc.
(b) Shaft sealing arrangements.
(c) Details of any shafting support or guide vanes used in the water jet system.
(d) Details and arrangements of inspection ports, their closing appliances and sealing arrangement, etc.
(e) Details and arrangements of protection gratings and their attachments.

2.1.3 When submitting the plans requested in *Pt 7, Ch 5, 2.1 Water jet propulsion systems - Construction 2.1.2*, details of the designers' loadings and their positions of application in the hull are to be submitted. These are to include maximum applied thrust, moments and tunnel pressures for which approval is sought.

2.1.4 All materials used in construction are to be manufactured and tested in accordance with the *Rules for the Manufacture, Testing and Certification of Materials, July 2021*(hereinafter referred to as the Rules for Materials).

2.1.5 Aluminium alloys are to be of suitable marine grades in accordance with the requirements of *Pt 7, Ch 2, 2 Materials*.

2.1.6 Irrespective of the material used, the strength and supporting structure of all tunnels are to be examined by direct calculation procedures which are to be submitted. In no case are the scantlings to be taken as less than the Rule requirements for the surrounding structure. The strength of the hull structure in way of tunnels is to be maintained. The structure is to be adequately reinforced and compensated as necessary. All openings are to be suitably reinforced and have radiused corners.

2.1.7 Consideration is to be given to providing the inlet to the tunnel with a suitable guard to prevent the ingress of large objects into the rotodynamic machinery. The dimensions of the guard are to strike a balance between undue efficiency loss due to flow restriction and viscous losses, the size of object allowed to pass and susceptibility to clog with weed and other flow restricting matter.

2.1.8 The inlet profile of the tunnel is to be so designed as to provide a smooth uptake of water over the range of craft operating trims and avoid significant separation of the flow into the rotating machinery.

2.1.9 Single or multiple water jet unit installations having a total rated power in excess of 500kW are to be contained within their own watertight compartment. Other arrangements for maintaining watertight integrity may be specially considered depending on the size and installation layout.

2.1.10 For details of machinery requirements, *see Pt 12, Ch 2 Water Jet Systems*.

2.2 Water jet propulsion systems - Installation

2.2.1 Standard units built for `off the shelf' supply and which include the duct are to be installed strictly in accordance with the manufacturer's instructions, *see also Pt 7, Ch 5, 2.1 Water jet propulsion systems - Construction 2.1.4*.

2.2.2 Integral water jet ducts are to be constructed in accordance with the manufacturer's requirements and the relevant plans submitted as required by *Pt 7, Ch 5, 2.1 Water jet propulsion systems - Construction*.

2.2.3 Where load is transmitted into the transom and/or bottom shell, the thickness of the plating adjacent to the jet unit is to be increased. The increase in thickness is to be not less than 50 per cent of the calculated transom and bottom plating thicknesses respectively or 8 mm, whichever is the greater. Such reinforcement is to extend beyond the surrounding stiffening structure.

2.2.4 For `bolted in' units, hull receiving rings are to be of a material compatible with the hull. Scantlings of the receiving rings are to be as required by the jet unit manufacturer and suitably edge prepared prior to welding in place. The receiving ring is to be installed using an approved welding procedure. Where a manufacturer's specification is not provided, full details are to be submitted.

2.2.5 Bolt sizes and spacings are to be specified by the manufacturer, and are to be of suitable marine grade, insulated as appropriate and locked by suitable means.

2.2.6 Where studs are proposed for the receiving ring(s), the remaining thickness below the depth of blind tap is to be not less than the bottom shell plating thickness plus 2 mm. Bottoms of all blind taps are to be free of sharp corners.

2.2.7 The use of approved alignment resins may be considered where accurate seating and faying surfaces are required. Details are to be submitted for consideration and approval.

2.2.8 Where a water jet unit forms an integral part of the hull structure, such units are to be installed using an approved weld procedure and in accordance with the manufacturer's instructions. Materials to be welded are to be of compatible specifications.

2.2.9 Water jet units transmitting thrust into the transom structure are to be supported by a system of radial, athwartship and vertical stiffening. Drawings are to be accompanied by a set of detailed structural calculations. Where complex installations are proposed, a finite element model may be submitted in lieu of direct calculations.

2.2.10 Water jet units transmitting thrust to a bottom shell connection or intermediate tunnel connection are to be supported by additional stiffening, the details of which are to be submitted.

2.3 Foil support arrangements

2.3.1 The materials and construction of the lifting surface will be considered on a case by case basis.

2.3.2 The design and performance of the lifting surface is outside the scope of classification. However, when submitting structural plans for the hull connection installation, the designer/Builder is to define:

(a) Operating mode, i.e. fully submerged or surface piercing.
(b) Maximum operational speed for which approval is sought.
(c) Maximum, direct, bending, shear and torque loads generated by the foil at the point of attachment(s).
(d) The type of profile or section used, e.g. N.A.C.A.
(e) Supply of lift/drag profile.
(f) If the foil is fixed, movable or retractable.
(g) If the foil is fitted with control surfaces.
(h) If the vertical leg(s) act as a rudder(s).
(i) If shaft liners are carried to the foils at which support arrangements are provided.
(j) If water intakes/scoops are fitted.
(k) If propulsion units are fitted.

2.3.3 The scantlings and arrangements of foils and their supporting structure will require to be specially considered in the following cases where:

(a) Propulsion units are incorporated within the foil.
(b) Foils carry shaft support arrangements.
(c) The foils are of novel design.

2.3.4 Where fully submerged foils are `built-in' to the hull, the attachment area is to be contained within a watertight compartment and the structural arrangements of *Pt 7, Ch 5, 2.4 Surface drive mountings* are to be complied with as appropriate.

2.3.5 Where foils are to be bolted to the structural foundation calculations are to be submitted to demonstrate that the effect of loading arising from high speed impact, grounding, fouling, etc. is limited to failure of the bolted connection. In all cases the structural and watertight integrity of the craft is to be maintained.

2.3.6 Attachment points of foils are to be contained within a watertight compartment.

2.3.7 Foils attached by riveted means are in addition to comply with *Pt 7, Ch 2, 4.24 Butt straps*.

2.3.8 Bow fairing doors fitted on forward retracting bow foils are to be weathertight and comply with *Pt 3, Ch 4 Closing Arrangements and Outfit*.

2.3.9 Aft bulkheads of bow foil compartments are to comply with the requirements for collision bulkheads as detailed in *Pt 7, Ch 3, 7.7 Collision bulkheads*.

2.3.10 Hydraulically operated retracting systems are to be equipped with low pressure and are to include a manual system of operation in the event of system failure.

2.3.11 A mechanical locking system is to be provided on retracting systems when the system is in both the operational and `stowed' conditions.

2.4 Surface drive mountings

2.4.1 Transoms through which surface drive systems pass and which are required to carry thrust, significant weight, torque, moment, etc. are to be adequately reinforced.

2.4.2 The thickness of transom plating in way is to be not less than 1,5 times the thickness of the adjacent plating or as advised by the drive manufacturer, whichever is the greater.

2.4.3 Steering rams are to be mounted on suitably reinforced areas of plating supported by additional internal stiffening, details of which are to be submitted for consideration.

2.5 Sea inlet scoops

2.5.1 Sea inlet scoops may be integral with or an appendage to the hull.

2.5.2 Scoops are to be suitably positioned to minimise ventilation.

2.5.3 Suitable protective arrangements are to be provided to minimise the ingress of debris. The net area through the proposed arrangement is to be not less than twice that of the valves connected to the scoop. Provision is to be made for clearing the scoops by the use of suitable means and proposals are to be submitted.

2.5.4 Scoops are to be contained within a watertight compartment.

2.5.5 The plating thickness in way of integral scoops is to be not less than 1,5 times the thickness of the adjacent shell plating, with additional reinforcement at the leading edge.

2.5.6 For craft navigating in ice, the arrangements will be specially considered on an individual basis.

2.6 Lifting appliance support arrangements

2.6.1 Crane pedestals are to be efficiently supported and in general, are to be carried through the deck and satisfactorily scarphed into the surrounding structure. Alternatively, crane pedestals may comprise a foundation, in which case the foundation and its supporting structure are to be of substantial construction. Proposals for other support arrangements will be specially considered.

2.6.2 The pedestal or proposed arrangement is to be designed with respect to the worst possible combinations of loads resulting from the crane self weight, live load, wind and crane accelerations together with those resulting from the craft's heel and trim.

2.6.3 Stowage arrangements are to be taken into account when calculating the loads applied to the pedestal.

2.6.4 The limiting stress coefficients for lifting appliance pedestals and foundation structural elements are given in *Table 7.3.1 Limiting stress coefficients for local loading*

2.6.5 The deck plating and underdeck stiffening in way of a lifting appliance pedestal are to be assessed using the same criteria used to assess the lifting appliance pedestal.

2.6.6 When submitting plans for the proposed foundation, the designer is to include design calculations covering the parameters indicated in *Pt 7, Ch 5, 2.6 Lifting appliance support arrangements 2.6.2* and *Pt 7, Ch 5, 2.6 Lifting appliance support arrangements 2.6.4*.

2.6.7 Insert plates are to be incorporated in the deck plating in way of crane foundations. The thickness of the insert plates is to be as required by the designer's calculations but is in no case is to be taken as less than 1,5 times the thickness of the adjacent attached plating.

2.6.8 All inserts are to have well radiused corners and be suitably edge prepared prior to welding. All welding in way is to be double continuous and full penetration where necessary. Tapers are to be not less than three to one.

2.6.9 The support arrangements for life-saving appliance davits and cranes are, in general, to be in accordance with *Pt 3, Ch 9, 6.5 Support structure for life-saving appliances* of the *Rules and Regulations for the Classification of Ships, July 2021*.

2.7 Skirt attachment

2.7.1 The design and scantlings of the skirt are outside the scope of classification, however the designer/builders are to submit their proposals in respect of the attachment detail. The following supporting information is to be submitted:

(a) cushion pressure,
(b) calculations demonstrating that the effect of damage to the flexible membrane and/or the retaining section arising from high speed impact, grounding, fouling, etc. will not compromise the structural and watertight integrity of the craft.

2.7.2 The skirt is to be securely attached around its periphery and is to be suitably reinforced by the use of backing plates.

2.7.3 Where the skirt is retained by bolting the retaining bars are to be as long as practicable with a fastener spacing of not more than 50 mm.

2.7.4 Where the design of the skirt is such that the flexible edge is retained by the use of a pre-formed channel, only the bolted hull connection of the preform to the hull structure is considered.

2.8 Trim tab arrangements

2.8.1 The shape, design and scantlings of the trim tabs are outside the scope of classification, however Lloyd's Register (hereinafter referred to as 'LR') is concerned with their attachment to the hull structure.

2.8.2 The designer/Builder is to submit the following :

(a) Detailed calculations indicating the maximum lift force generated by the tab for which acceptance is sought together with the corresponding speed and displacement.
(b) Details and calculations of the hull attachment.
(c) Details and calculations of the local internal reinforcement in way of the attachment.

2.8.3 Bearing materials used are to be of an approved type.

2.8.4 Fully submerged retractable trim tabs will be specially considered on a case by case basis.

2.9 Spray rails

2.9.1 Spray rails may be integrated into the hull structure or added in the form of an appendage on completion of the hull shell.

2.9.2 Where spray rails are integrated, they are to have a plating thickness not less than the adjacent bottom shell and additionally have a section modulus and inertia equivalent to that required for a longitudinal stiffener in the same position.

2.9.3 Where spray rails are added as an appendage, they are to be attached by double continuous welding and are additionally to comply with the strength requirements of *Pt 7, Ch 5, 2.9 Spray rails 2.9.2*.

2.9.4 Spray rails are to be supported by the internal stiffening arrangements and by additional local reinforcement as necessary.

2.9.5 In no case are the toes of spray rails to terminate on unsupported plating.

2.10 Other lifting surfaces

2.10.1 Other lifting surfaces not specifically covered by the Rules will be individually considered on the basis of submitted direct calculations.

2.10.2 Structure or hull shapes above the running waterline designed to generate aerodynamic lift may be individually considered on a case by case basis

2.10.3 Aerodynamic, hydrodynamic and aero-hydrodynamic stability are outside the scope of classification and are subject to the approval of the National Administration concerned.

2.11 Propeller ducting

2.11.1 Where propellers are fitted within ducts/tunnels the plating thickness in way of the blades is to be increased by 50 per cent.

2.11.2 The tunnel wall in way of the propeller blades is to be additionally stiffened.

2.12 Ride control ducting and installation for Surface Effect Ships (SES)

2.12.1 Ducts penetrating the side inboard shell plating are to comply with the scantling requirements for side inboard structures, over their entire length in the appropriate material.

2.12.2 Ducts penetrating the wet deck are to comply with the scantling requirements for wet deck structures over their entire length in the appropriate material.

2.12.3 Open ends of ducts are to be fitted with a suitable protective grille.

2.12.4 The vent assembly, its design, construction and operation are outside the scope of classification and is the responsibility of the ride control system designer.

2.12.5 Details of the installation and securing arrangements of the vent valve assembly into the duct are to be submitted for approval.

2.13 Ramp supporting structure

2.13.1 The support structure (including hinges) in way of the interface between a ramp and the craft is to be assessed in accordance with the appropriate criteria given in *Ch 6, 2 Loading and design criteria* of the *Code for Lifting Appliances in a Marine Environment, July 2021*.

2.13.2 The loads that the ramp supporting structure will be subjected to are to be submitted by the designer or Shipbuilder. These loads are to be calculated in accordance with *Ch 6, 2 Loading and design criteria* of the *Code for Lifting Appliances in a Marine Environment, July 2021*. Load cases calculated in accordance with alternative standards can be accepted subject to agreement with LR.

2.13.3 Loads already existing in the supporting structure (other than those from the ramp) are to be superimposed if applicable.

2.13.4 Ramps forming part of the watertight integrity of the hull are also to be assessed in accordance with the applicable scantling requirements.

■ *Section 3* Vehicle decks

3.1 General

3.1.1 These requirements are applicable to longitudinally or transversely framed craft intended for the carriage of wheeled vehicles, or where wheeled vehicles are to be used for cargo handling.

3.1.2 The deck and supporting structure are to be designed on the basis of the maximum loading to which they may be subjected in service. Where applicable, the hatch covers are to be similarly designed. In no case, however, are the scantlings to be less than would be required for a weather or cargo deck, or hatch cover, as applicable.

3.1.3 Details of the deck loading resulting from the proposed stowage or operation of vehicles are to be supplied by the Builder. These details are to include axle and wheel spacing, the wheel load, type of tyre and tyre print dimensions for the vehicles. The vehicle types and wheel loads for which the vehicle decks, including hatch covers where applicable, have been approved are to be included in the craft's documentation and contained in a notice displayed on each deck. For design purposes, the wheel loading is to be taken as not less than 3,0 kN.

3.1.4 The scantling requirements are based on structural strength and limitations on stress and deflection, with no allowance made for wear and tear. Local reinforcement is to be fitted as necessary, particularly in way of vehicle lanes and passenger routes.

3.1.5 The webs of vehicle deck stiffening members are in no cases to be scalloped.

3.2 Definitions

3.2.1 **Load area**. The load area is defined as the footprint area of an individual wheel or the area enclosing a group of wheels when the distance between footprints is less than the smaller dimension of the individual prints.

3.3 Deck plating

3.3.1 The thickness, t_p, of vehicle deck plating is to be taken as not less than:

$$t_p = \frac{\alpha s}{1370\sqrt{k_a}} \text{ mm}$$

where

P_1 = corrected patch load, in tonnes, obtained from *Table 5.3.1 Deck plate thickness calculation*

α = thickness coefficient obtained from *Figure 5.3.1 Tyre print chart*

s = secondary stiffener spacing, in mm

β_p = tyre print coefficient used in *Figure 5.3.1 Tyre print chart*

$$= log_{10}\left(\frac{3,5\, P_1 K_a{}^2}{s^2} \times 10^7\right)$$

s and k_a are as defined in *Pt 7, Ch 5, 1.2 Symbols and definitions*.

Table 5.3.1 Deck plate thickness calculation

<table>
<tr><th>Symbols</th><th colspan="2">Expression</th></tr>
<tr><td rowspan="5">a, s, u, and v as defined in Figure 5.3.1 Tyre print chart

n= tyre correction factor as detailed in Table 5.3.2 Tyre correction factor, n

P_1 = corrected patch load, in tonnes

λ = dynamic magnification factor

P_w = load, in tonnes, on the tyre print. For closely spaced wheels the shaded area shown in Figure 5.3.1 Tyre print chart may be taken as the combined print

λ = dynamic magnification factor

φ_1 = patch aspect ratio correction factor

φ_2 = panel aspect ratio correction factor

φ_3 = wide patch load factor</td><td colspan="2">$P_1 = \varphi_1 \varphi_2 \varphi_3 \lambda P_w$</td></tr>
<tr><td>$\varphi_1 = \dfrac{2v_1 + 1,1s}{u_1 + 1,1s}$</td><td>$v_1 = v$, but $\leq s$

$u_1 = u$, but $\leq a$</td></tr>
<tr><td>$\varphi_2 = 1,0$

$= \dfrac{1}{1,3 - \dfrac{0,3}{s}\left(a - u\right)}$

$= 0,77\dfrac{a}{u}$</td><td>$u \leq (a - s)$

for $a \geq u > (a - s)$

for $u > a$</td></tr>
<tr><td>$\varphi_3 = 1,0$

$= 0,6(s/v) + 0,4$

$= 1,2(s/v)$</td><td>for $v < s$

for 1,5 > (v/s) > 1,0

for $(v/s) \geq 1,5$</td></tr>
<tr><td colspan="2">λ = 1,25 for craft operating in G1
= (1 + 0,35n) for craft operating in G2
= (1 + 0,385n) for craft operating in G2A
= (1 + 0,42n) for craft operating in G3
= (1 + 0,49n) for craft operating in G4
= (1 + 0,56n) for craft operating in G5
= (1 + 0,70n) for craft operating in G6

G1, G2, G2A, G3, G4, G5 and G6 as defined in Pt 1, Ch 2, 3.5 Service area restriction notations 3.5.5</td></tr>
</table>

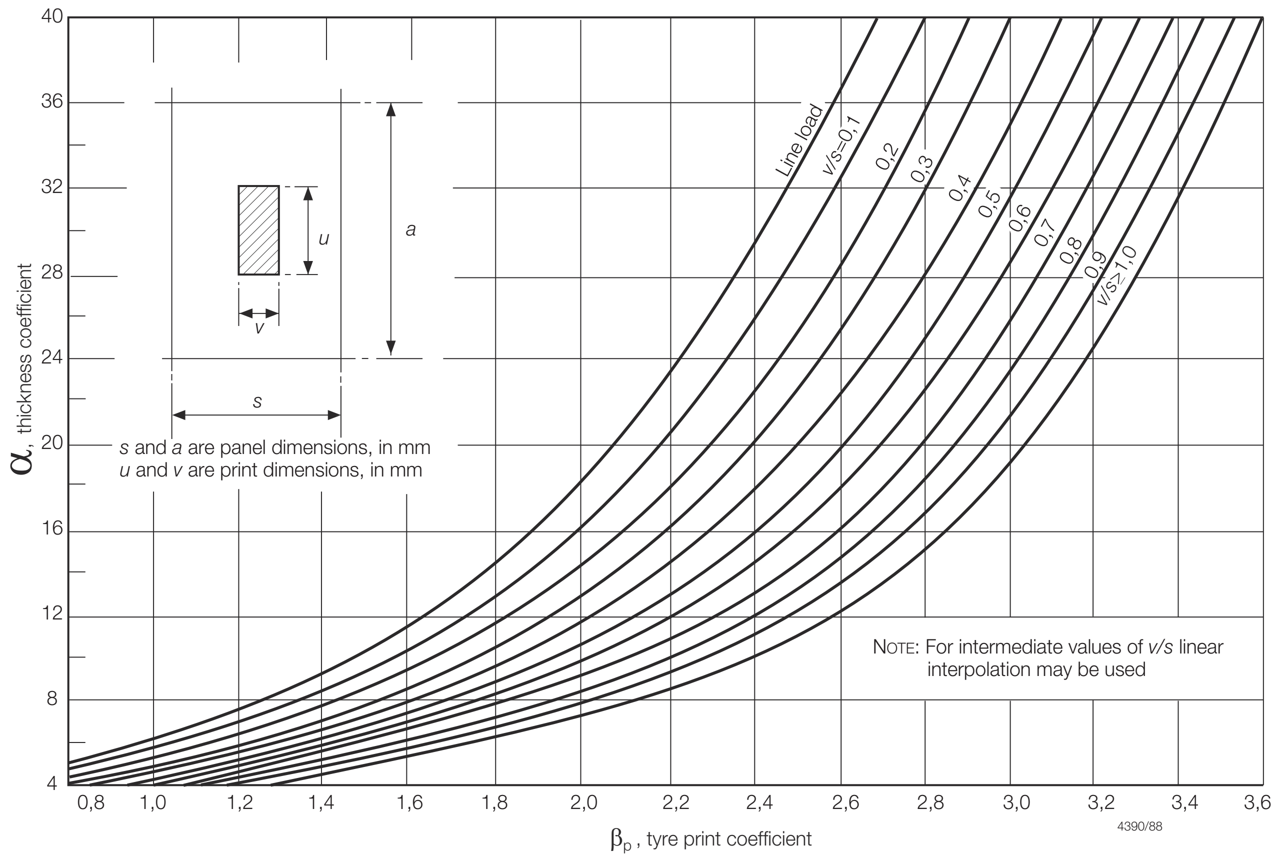


Figure 5.3.1 Tyre print chart

3.4 Secondary stiffening

3.4.1 The scantlings of vehicle deck stiffeners are to be as required to satisfy the most severe arrangement of print wheel loads in conjunction with the cargo/weather deck design head.

3.4.2 The minimum requirements for section modulus, inertia and web area of vehicle deck secondary stiffeners subject to wheel loading are to be calculated in accordance with *Table 5.3.3 Secondary stiffener requirements*, *see also Figure 5.3.1 Tyre print chart* and *Table 5.3.2 Tyre correction factor, n* .

Table 5.3.2 Tyre correction factor, *n*

Number of wheels in idealised patch	Pneumatic tyres correction factor, n	Solid rubber tyres correction factor, n
1	0,6	0,8
2 or more	0,75	0,9

Table 5.3.3 Secondary stiffener requirements

Scantling requirement	Load case	
	$d \leq l$	$d > l$
Section modulus (Z) (cm^3)	$Z = \left(\dfrac{P k_w (3l^2 - d^2)}{24 l f_\sigma \sigma_a} \right) \times 10^3 + Z_{dk}$	$Z = \left(\dfrac{k_w P l^2}{10 d f_\sigma \sigma_a} \right) \times 10^3 + Z_{dk}$
Inertia (I) (cm^4)	$I = \left(\dfrac{f_\delta P k_w (2l^3 - 2d^2 l + d^3)}{384\, E\, l} \right) \times 10^5 + I_{dk}$	$I = \left(\dfrac{f_\delta k_w P l^3}{384\, E\, d} \right) \times 10^5 + I_{dk}$
Web area (A_w) (cm^2)	$A_w = \dfrac{10 P k_w (m^3 - 2m^2 + 2)}{2 f_\tau \tau_a} + A_{dk}$ where $m = d/l$	$A_w = \dfrac{k_w P l}{2 d f_\tau \tau_a} + A_{dk}$

Symbols

P = maximum effective load per wheel or group of wheels, in kN

l = overall secondary stiffener length, in metres

s = stiffener spacing, in metres

d = dimension of load area parallel to stiffener axis, in metres

E = Young's modulus of elasticity of material, in N/mm^2

w = dimension of load area perpendicular to stiffener axis, in metres

k_w = lateral loading factor

=

= 1 for $w \leq s$

= s/w for $w > s$

f_σ = limiting bending stress coefficient taken from *Table 7.3.1 Limiting stress coefficients for local loading* in Chapter 7

f_τ = limiting shear stress coefficient taken from *Table 7.3.1 Limiting stress coefficients for local loading* in Chapter 7

f_δ = limiting deflection coefficient taken from *Table 7.3.2 Limiting stress coefficients for global loading* in Chapter 7

σ_a = 0,2% proof stress of material, in N/mm^2

τ_a = shear stress of the alloy, in N/mm^2

= $\dfrac{\sigma_a}{\sqrt{3}}$

Note

Z_{dk}, I_{dk}, A_{dk} = For vehicle decks, stiffener requirements to be determined in accordance with *Pt 7, Ch 3, 8.7 Strength/weather deck stiffening* and *Pt 7, Ch 3, 8.10 Cargo deck stiffening* using the appropriate design pressures, but not to be taken as less than 2kN/m^2.

= For helicopter decks, stiffener requirements to be determined in accordance with *Pt 7, Ch 3, 8.7 Strength/weather deck stiffening* using the uniformly distributed loads given in *Table 5.6.2 Design load cases for deck stiffening and supporting structure*.

3.4.3 When two or more load areas are located simultaneously on the same stiffener span, the scantling requirements are to be specially considered on the basis of direct calculation.

3.4.4 Where continuous secondary stiffeners pass through the webs of primary members, they are to be fully collared or lugged in way. The shear stresses at the connections are to be in compliance with *Table 7.3.1 Limiting stress coefficients for local loading* in Chapter 7.

3.5 Primary stiffening

3.5.1 The scantlings of vehicle deck primary girders and transverse web frames are to be determined on the basis of direct calculation in association with the limiting permissible stress and deflection criteria contained in *Pt 7, Ch 7 Failure Modes Control*.

3.6 Securing arrangements

3.6.1 Details of the connections to the hull of vehicle securing arrangements are to be submitted for approval.

3.6.2 Deck fittings in way of vehicle lanes are to be recessed.

3.6.3 The vehicle deck structure is to be of adequate strength for the upward forces imposed at fixed securing points. Local reinforcement is to be fitted as necessary.

3.7 Access

3.7.1 Bow doors are to comply with the requirements of *Pt 7, Ch 5, 4 Bow doors*.

3.7.2 Where access to the vehicle deck is provided by side and stern doors the doors are to have scantlings equivalent to the structure in which they are fitted, *see also Pt 3, Ch 4, 4 Side and stern doors and other shell openings*.

3.7.3 Doors providing pedestrian access between vehicle decks and accommodation spaces are to be gastight, have scantlings equivalent to the surrounding structure and where applicable are to comply with the requirements of *Pt 17 Fire Protection, Detection and Extinction*.

3.8 Hatch covers

3.8.1 The scantlings and arrangements of hatches and hatch covers located within vehicle decks are to be not less than that required by the Rules for the supporting structure in which such hatches are fitted. In general the end fixity of primary stiffening members is to be taken as simply supported. Local and secondary stiffening members may be either partially or fully fixed at their end connections dependent upon the proposed arrangement.

3.8.2 In no case, however, are the scantlings of plating and stiffeners to be less than would be required for a weather or cargo deck, or hatch cover, as applicable.

3.8.3 Where unusual arrangements of hatch cover stiffening are proposed, the scantlings of plating and stiffeners may be determined by direct calculations using a two-dimensional grillage model. A copy of the calculations is to be submitted.

3.9 Heavy and special loads

3.9.1 Where heavy or special loads are proposed to be carried, the scantlings and arrangements of the deck structure will be individually considered on the basis of submitted calculations.

3.9.2 Due account is to be taken of the acceleration levels due to craft motion as applicable to particular items of heavy mass such as vehicles, containers, pallets, etc.

3.10 Direct calculations

3.10.1 LR will consider direct calculations for the derivation of scantlings as an alternative to and equivalent to those derived by Rule requirements. The assumptions made and the calculation procedures used are to be submitted for appraisal in accordance with *Pt 3, Ch 1, 2 Direct calculations*.

■ *Section 4* Bow doors

4.1 Application

4.1.1 The requirements of this Section are applicable to the arrangement, strength and securing of bow doors, both the visor and the side opening type doors, and inner doors leading to a complete or long forward enclosed superstructure.

4.1.2 Other types of bow door will be specially considered.

4.2 General

4.2.1 The attention of Owners and Builders is drawn to the additional statutory regulations for bow doors that may be imposed by the National Authority.

4.2.2 Bow doors are to be situated above the freeboard deck. A watertight recess in the freeboard deck located forward of the collision bulkhead and above the deepest waterline fitted for arrangement of ramps or other related mechanical devices may be regarded as a part of the freeboard deck.

4.2.3 An inner door is to be fitted. The inner door is to be part of the collision bulkhead. The inner door need not be fitted directly above the bulkhead below, provided it is located within the limits specified for the position of the collision bulkhead, *see Pt 3, Ch 2, 4 Bulkhead arrangements*. A vehicle ramp may be arranged for this purpose, provided its position complies with *Pt 3, Ch 2, 4 Bulkhead arrangements* and the ramp is weathertight over its complete length. In this case the upper part of the ramp higher than 2,3 m above the freeboard deck may extend forward of the limit specified in *Pt 3, Ch 2, 4 Bulkhead arrangements*. If this is not possible a separate inner weathertight door is to be installed, as far as practicable within the limits specified for the position of the collision bulkhead.

4.2.4 Bow doors are to be fitted as to ensure tightness consistent with operational conditions and to give effective protection to inner doors. Inner doors forming part of the collision bulkhead are to be weathertight over the full height of the cargo space and arranged with fixed sealing supports on the aft side of the doors.

4.2.5 Bow doors and inner doors are to be arranged so as to preclude the possibility of the bow door causing structural damage to the inner door or to the collision bulkhead in the case of damage to or detachment of the bow door. If this is not possible, a separate inner weathertight door is to be installed, as indicated in *Pt 7, Ch 5, 4.2 General 4.2.3*.

4.2.6 The requirements for inner doors are based on the assumption that vehicles are effectively lashed and secured against movement in the stowed position.

4.3 Symbols and definitions

4.3.1 The symbols used in this Section are defined as follows:

A_s = area stiffener web in cm^2

A_x = area, in m^2, of the transverse vertical projection of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, whichever is the lesser, as shown in *Figure 5.4.2 Bow visor (upward hinging)*

A_y = area, in m^2, of the longitudinal vertical projection of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, whichever is the lesser

A_z = area of the horizontal projection of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, in m^2, whichever is the lesser, as shown in *Figure 5.4.2 Bow visor (upward hinging)*

a_{bv} = vertical distance, in m, from visor pivot to the centroid of the transverse vertical projected area of the visor door, as shown in *Figure 5.4.2 Bow visor (upward hinging)*

b_{bv} = horizontal distance, in m, from visor pivot to the centroid of the horizontal projected area of the visor door, as shown in *Figure 5.4.2 Bow visor (upward hinging)*

c_{bv} = horizontal distance, in m, from visor pivot to the centre of gravity of visor mass, as shown in *Figure 5.4.2 Bow visor (upward hinging)*

h = height of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, in metres, whichever is the lesser, as shown in *Figure 5.4.1 Measurement of αf and βe*

k_a = alloy factor

= $125/\sigma_a$

Q_{bd} = shear force, in kN, in the stiffener calculated by using uniformly distributed external pressure P_e as given in *Pt 7, Ch 5, 4.5 Design loads 4.5.1*

W_{bv} = mass of the visor door, in tonnes

W = breadth of the door at a height h/2 above the bottom of the door, in metres, as shown in *Figure 5.4.1 Measurement of αf and βe*

l_d = length of the door at a height h/2 above the bottom of the door, in metres, as shown in *Figure 5.4.2 Bow visor (upward hinging)*

τ = shear stress, in N/mm^2

σ = bending stress, in N/mm^2

σ_a = material yield stress, in N/mm^2

σ_{eq} = equivalent stress, in N/mm^2

= $\sqrt{\sigma^2 + 3\tau^2}$.

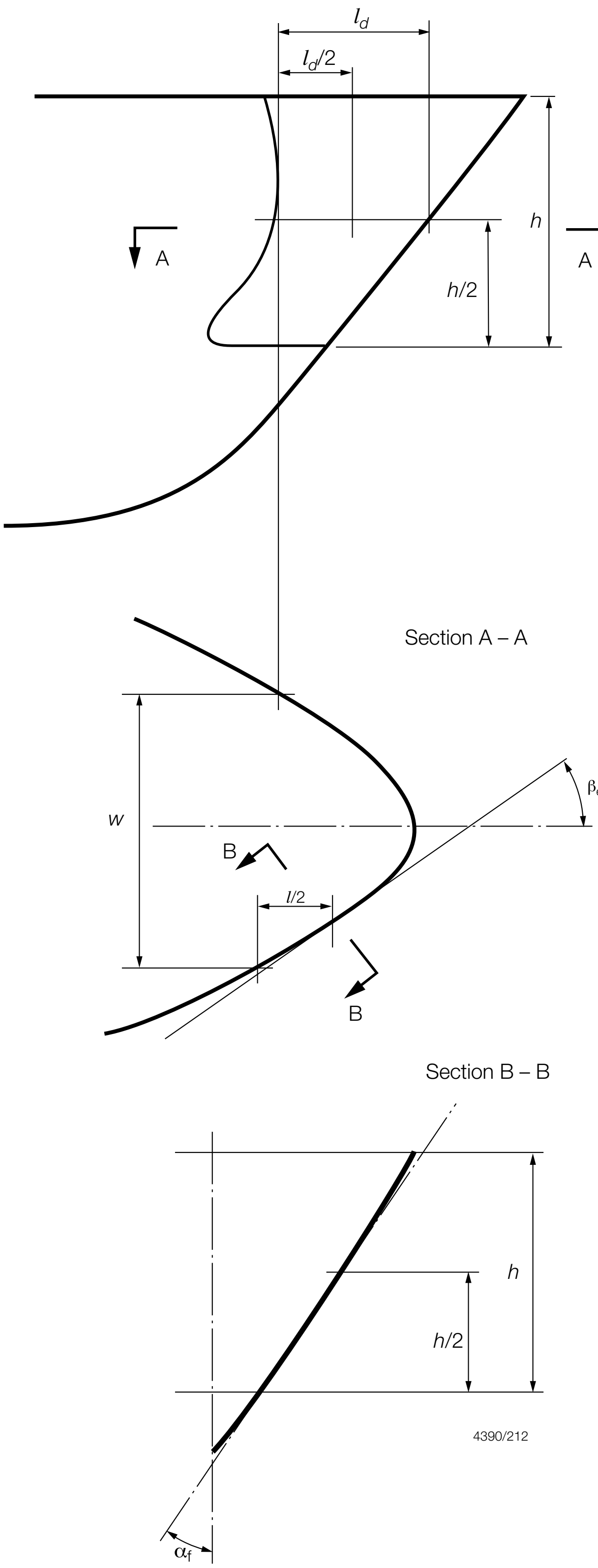


Figure 5.4.1 Measurement of α_f and β_e

4.3.2 **Locking device**. A device that locks a securing device in the closed position.

4.3.3 **Securing device**. A device used to keep the door closed by preventing it from rotating about its hinges.

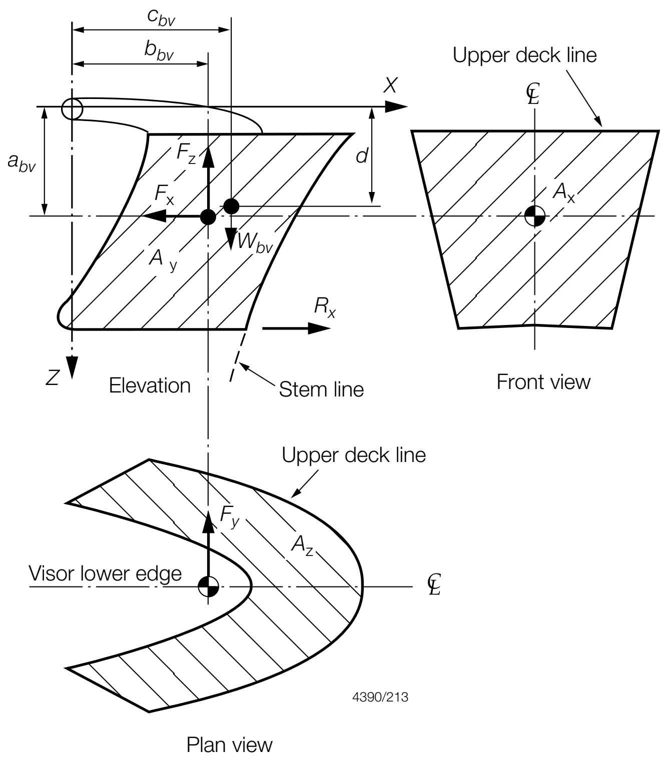


Figure 5.4.2 Bow visor (upward hinging)

4.3.4 **Side-opening doors**. Side-opening doors are opened either by rotating outwards about a vertical axis through two or more hinges located near the outboard edges or by horizontal translation by means of linking arms arranged with pivoted attachments to the door and the craft. It is anticipated that side-opening doors are arranged in pairs.

4.3.5 **Supporting device**. A device used to transmit external or internal loads from the door to a securing device and from the securing device to the craft's structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, that transmits loads from the door to the craft's structure.

4.3.6 **Visor doors**. Visor doors are opened by rotating upwards and outwards about a horizontal axis through two or more hinges located near the top of the door and connected to the primary structure of the door by longitudinally arranged lifting arms.

4.4 Strength criteria

4.4.1 Scantlings of the primary members, securing and supporting devices of bow doors and inner doors are to be able to withstand the design loads defined in *Pt 7, Ch 5, 4.5 Design loads*. The shear, bending and equivalent stresses are not to exceed $43/k_a$ N/mm^2, $64/k_a$ N/mm^2 and $80/k_a$ N/mm^2 respectively.

4.4.2 The buckling strength of primary members is to be verified as being adequate, *see Pt 7, Ch 7, 4 Buckling control*.

4.4.3 For metal to metal bearings in securing and supporting devices, the nominal bearing pressure calculated by dividing the design force by the projected bearing area is not to exceed 80 per cent of the yield stress of the bearing material. For other bearing materials, the permissible bearing pressure is to be determined according to the manufacturer's specification.

4.4.4 The arrangement of securing and supporting devices is to be such that threaded bolts do not carry support forces. The maximum tension in way of threads of steel bolts not carrying support forces is not to exceed $125/k_s$ N/mm^2.

4.5 Design loads

4.5.1 The design external pressure, P_e, for the determination of scantlings for primary members, securing and supporting devices of bow doors is taken to be not less than the following:

$$P_e = 2,75\,\lambda_G C_H \left(0,22 + 0,15 \tan \alpha_f\right) \left(0,4 V_{max} \sin \beta_e + 0,6 L_R^{0,5}\right)^2 \text{ kN/m}^2$$

where

V_{max} = maximum speed in knots as defined in *Pt 1, Ch 2, 2.2 Definitions 2.2.11*.

L_R = Rule length of craft, in m as defined in *Pt 3, Ch 1, 6 Definitions*

λ_G = Service group factor for mono-hull craft, *see Pt 1, Ch 2 Classification Regulations*

= 0,5 for Group 1 and 2

= 0,6 for Group 3

= 0,8 for Group 4

= 1,0 for Groups 5 and 6

= For multi-hull craft, λ_G will be specially considered and may be reduced where the freeboard is significant

C_H = 0,0125L_R for L_R < 80 m

= 1,0 for $L_R \geq 80$ m

α_f = flare angle at the point to be considered, defined as the angle between a vertical line and the tangent to the side shell plating, measured in a vertical plane normal to the horizontal tangent to the shell plating, *see Figure 5.4.1 Measurement of αf and βe*

β_e = entry angle at the point to be considered, defined as the angle between a longitudinal line parallel to the centreline and the tangent to the shell plating in a horizontal plane, *see Figure 5.4.1 Measurement of αf and βe*

4.5.2 The design external forces, F_x, F_y and F_z, in kN, for the determination of scantlings of securing and supporting devices of bow doors are taken to be not less than $P_e A_x$, $P_e A_y$ and $P_e A_z$ respectively. Where P_e is the external pressure, defined in *Pt 7, Ch 5, 4.5 Design loads 4.5.1*, with the flare angle, α_f, and the entry angle, β_e, measured at the point on the bow door, $l_d/2$ aft of the stem line on the plane $h/2$ above the bottom of the door, as shown in *Figure 5.4.1 Measurement of αf and βe*. A_x, A_y, A_z and h as defined in *Pt 7, Ch 5, 4.3 Symbols and definitions 4.3.1*.

4.5.3 For bow doors, including bulwark, of unusual form or proportions, the areas used for the determination of the design values of external forces will be specially considered.

4.5.4 For visor doors the closing moment, M_y, under external loads, is to be taken as :

$$M_y = F_x a_{bv} + 10 W_{bv} c_{bv} - F_z b_{bv} \text{ kNm}$$

where

W_{bv}, a_{bv}, b_{bv} and c_{bv} are as defined in *Pt 7, Ch 5, 4.3 Symbols and definitions 4.3.1*

F_x and F_z are as defined in *Pt 7, Ch 5, 4.5 Design loads 4.5.2*.

4.5.5 The lifting arms of a visor and its supports are to be dimensioned for the static and dynamic forces applied during the lifting and lowering operations, and a minimum wind pressure of 1,5kN/m^2 is to be taken.

4.5.6 The design external pressure, in kN/m^2, for the determination of scantlings for primary members, securing and supporting devices and surrounding structure of inner doors is to be taken as the greater of 0,45L_R and 10h_2, where h_2 is the distance, in m, from the load point to the top of the cargo space and L_R as defined in *Pt 3, Ch 1, 6.2 Principal particulars 6.2.1*.

4.5.7 The design internal pressure for the determination of scantlings for securing devices of inner doors is not to be taken less than 25 kN/m^2.

4.6 Scantlings of bow doors

4.6.1 The strength of bow doors is to be commensurate with that of the surrounding structure.

4.6.2 Bow doors are to be adequately stiffened and means are to be provided to prevent lateral or vertical movement of the doors when closed. For visor doors adequate strength for the opening and closing operations is to be provided in the connections of the lifting arms to the door structure and to the craft structure.

4.6.3 The thickness of the bow plating is not to be less than that required for the side shell plating, using bow door stiffener spacing, but in no case less than the minimum required thickness of fore end shell plating.

4.6.4 The section modulus of horizontal or vertical stiffeners is not to be less than that required for end framing. Consideration is to be given, where necessary, to differences in fixity between craft's frames and bow doors stiffeners.

4.6.5 The stiffener webs are to have a net sectional area A_s, not less than:

$$A_s = \frac{12,5 Q_{bd}}{\sigma_a} \text{ cm}^2$$

where A_s, Q_{bd} and σ_a are as defined in *Pt 7, Ch 5, 4.3 Symbols and definitions 4.3.1*.

4.6.6 The bow door secondary stiffeners are to be supported by primary members constituting the main stiffening of the door.

4.6.7 The primary members of the bow door and the hull structure in way are to have sufficient stiffness to ensure integrity of the boundary support of the door.

4.6.8 Scantlings of the primary members are generally to be supported by direct calculations in association with the external pressure given in *Pt 7, Ch 5, 4.5 Design loads 4.5.1* and permissible stresses given in *Pt 7, Ch 5, 4.4 Strength criteria 4.4.2*.

4.7 Scantlings of inner doors

4.7.1 Scantlings of the primary members are generally to be supported by direct calculations in association with the external pressure given in and permissible stresses given in *Pt 7, Ch 5, 4.4 Strength criteria 4.4.1*. In general, formulae for simple beam theory may be applied.

4.7.2 Where inner doors also serve as a vehicle ramps, the scantlings are not to be less than those required for vehicle decks.

4.7.3 The distribution of the forces acting on the securing and supporting devices is, in general, to be supported by direct calculations taking into account the flexibility of the structure and actual position and stiffness of the supports.

4.8 Securing and supporting of bow doors

4.8.1 Bow doors are to be fitted with adequate means of securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure. The hull supporting structure in way of the bow doors is to be suitable for the same design loads and design stresses as the securing and supporting devices. Where packing is required, the packing material is to be of a comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered. Maximum design clearance between securing and supporting devices is, in general, not to exceed 3 mm. A means is to be provided for mechanically fixing the door in the open position.

4.8.2 Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be included and considered to calculate the reaction forces acting on the devices. Small and/or flexible devices such as cleats intended to provide load compression of the packing material are, in general, not to be included in the calculations called for in *Pt 7, Ch 5, 4.8 Securing and supporting of bow doors 4.8.8*. The number of securing and supporting devices are, in general, to be the minimum practical whilst taking into account the requirements for redundant provision given in *Pt 7, Ch 5, 4.8 Securing and supporting of bow doors 4.8.9* and *Pt 7, Ch 5, 4.8 Securing and supporting of bow doors 4.8.10* and the available space for adequate support in the hull structure.

4.8.3 For opening outwards visor doors, the pivot arrangement is generally to be such that the visor is self closing under external loads, that is $M_y > 0$. Moreover, the closing moment, M_y, as given in *Pt 7, Ch 5, 4.5 Design loads 4.5.4* is to be not less than:

$$M_{ya} = 10 W_{bv} c_{bv} + 0,1\left(a_{bv}^{\ 2} + b_{bv}^{\ 2}\right)^{0,5}\left(F_x^{\ 2} + F_z^{\ 2}\right)^{0,5}$$

where

W_{bv}, a_{bv}, b_{bv} and c_{bv} are as defined in *Pt 7, Ch 5, 4.3 Symbols and definitions 4.3.1*

F_x and F_z as defined in *Pt 7, Ch 5, 4.5 Design loads 4.5.2*.

4.8.4 Securing and supporting devices are to be adequately designed so that they can withstand the reaction forces within the permissible stresses given in *Pt 7, Ch 5, 4.4 Strength criteria 4.4.1*.

4.8.5 For **visor doors** the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self weight of the door.

Case 1	F_x and F_z.
Case 2	0,7F_y acting on each side separately together with 0,7F_x and 0,7F_z.

where F_x, F_y and F_z are to be determined as indicated in *Pt 7, Ch 5, 4.5 Design loads 4.5.2* and applied at the centroid of projected areas.

4.8.6 For **side-opening doors** the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self weight of the door:

Case 1	F_x, F_y and F_z acting on both doors.
Case 2	0,7 F_x and 0,7F_z acting on both doors and 0,7F_y acting on each door separately.

where

F_x, F_y and F_z are to be determined as indicated in *Pt 7, Ch 5, 4.5 Design loads 4.5.2* and applied at the centroid of projected areas.

4.8.7 The support forces as determined according to *Pt 7, Ch 5, 4.8 Securing and supporting of bow doors 4.8.5* and *Pt 7, Ch 5, 4.8 Securing and supporting of bow doors 4.8.6* are to generally give rise to a zero moment about the transverse axis through the centroid of the area A_x. For visor doors, longitudinal reaction forces of pin and/or wedge supports at the door base contributing to this moment are not to be of the forward direction.

4.8.8 The distribution of the reaction forces acting on the securing and supporting devices may require to be supported by direct calculations taking into account the flexibility of the hull structure and the actual position and stiffness of the supports.

4.8.9 The arrangement of securing and supporting devices in way of these securing devices is to be designed with redundancy so that in the event of failure of any single securing or supporting device the remaining devices are capable of withstanding the reaction forces without exceeding by more than 20 per cent the permissible stresses as given in *Pt 7, Ch 5, 4.4 Strength criteria 4.4.1*.

4.8.10 For **visor doors**, two securing devices are to be provided at the lower part of the door, each capable of providing the full reaction force required to prevent opening of the door within the permissible stresses given in *Pt 7, Ch 5, 4.4 Strength criteria 4.4.1*. The opening moment, M_o, to be balanced by this reaction force, is not to be taken less than:

$$M_o = 10W_{bv}d_{bv} + 5A_x a_{bv} \text{ kNm}$$

where

W_{bv}, A_x, d_{bv} and a_{bv} are as defined in *Pt 7, Ch 5, 4.3 Symbols and definitions 4.3.1*.

4.8.11 For **visor doors**, the securing and supporting devices excluding the hinges should be capable of resisting the vertical design force (F_z - 10W_{bv}), in kN, within the permissible stresses given in *Pt 7, Ch 5, 4.4 Strength criteria 4.4.1*.

4.8.12 All load transmitting elements in the design load path, from door through securing and supporting devices into the craft structure, including welded connections, are to be the same strength.

4.8.13 For **side-opening doors**, thrust bearing has to be provided in way of girder ends at the closing of the two leaves to prevent one leaf to shift towards the other one under effect of unsymmetrical pressure, *see Figure 5.4.3 Typical thrust bearing*. Each part of the thrust bearing has to be kept secured on the other part by means of securing devices. Any other arrangements serving the same purpose are to be submitted for appraisal.

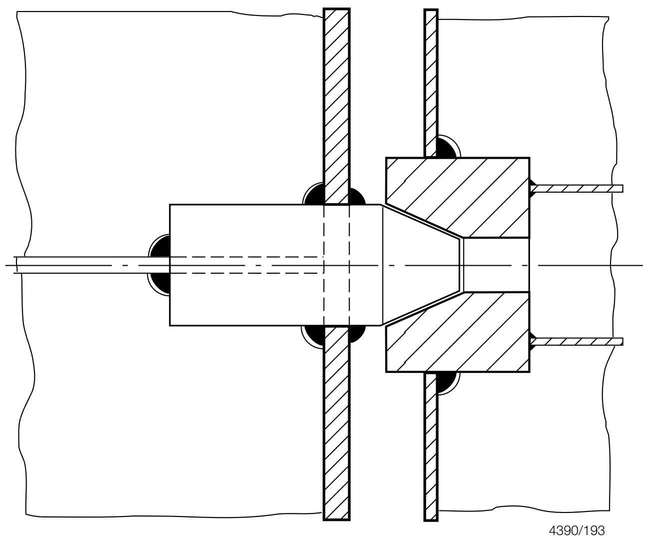


Figure 5.4.3 Typical thrust bearing

4.9 Securing and locking arrangement

4.9.1 Securing devices are to be simple to operate and easily accessible. Securing devices are to be equipped with mechanical locking arrangement (self locking or separate arrangement), or be of the gravity type. The opening and closing systems as well as securing and locking devices are to be interlocked in such a way that they can only operate in the proper sequence.

4.9.2 Bow doors and inner doors giving access to vehicle decks are to be provided with an arrangement for remote control, from a position above the freeboard deck, of:

(a) the closing and opening of the doors, and
(b) associated securing and locking devices for every door.

Indication of the open/closed position of every door and every securing and locking device is to be provided at the remote control stations. The operating panels for operation of doors are to be inaccessible to unauthorised persons. A notice plate, giving instructions to the effect that all securing devices are to be closed and locked before leaving harbour, is to be placed at each operating panel and is to be supplemented by warning indicator lights.

4.9.3 Where hydraulic securing devices are applied, the system is to be mechanically lockable in the closed position so that in the event of loss of the hydraulic fluid, the securing devices remain locked. The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits when in the closed position.

4.9.4 Separate indicator lights and audible alarms are to be provided on the navigation bridge and on the operating panel to show that the bow door and inner door are closed and that their securing and locking devices are properly positioned. The indication panel is to be provided with a lamp test function. The indicator lights are to be provided with a permanent power supply, further, arrangements are to be such that it is not possible to turn off these lights in service.

4.9.5 The indicator system is to be designed on the fail-safe principle and is to show by visual alarms if the door is not fully closed and not fully locked and by audible alarms if securing devices become open or locking devices become unsecured. The power supply for the indicator system is to be independent of the power supply for operating and closing the doors. The sensors of the indicator system are to be protected from water, ice formation and mechanical damages.

4.9.6 The indication panel on the navigation bridge is to be equipped with a mode selection function `harbour/sea voyage', so arranged that audible alarm is given if the craft leaves harbour with the bow door or inner door not closed and with any of the securing devices not in the correct position.

4.9.7 A water leakage detection system with audible alarm and television surveillance are to be arranged to provide an indication to the navigation bridge and to the engine control room of leakage through the inner door.

4.9.8 Between the bow door and the inner door a television surveillance system is to be fitted with a monitor on the navigation bridge and in the engine control room. The system is to be able to monitor the position of doors and a sufficient number of their securing devices. Special consideration is to be given for lighting and contrasting colour of objects under surveillance.

4.9.9 A drainage system is to be arranged in the area between bow door and ramp, as well as in the area between the ramp and inner door where fitted. The system is to be equipped with an audible alarm function to the navigation bridge for water level in these areas exceeding 0,5 m above the car deck level.

4.10 Operating and Maintenance Manual

4.10.1 An Operating and Maintenance Manual for the bow door and inner door is to be provided on board and contain necessary information on:

(a) main particulars and design drawings,
(b) service conditions, e.g. service area restrictions, acceptable clearances for supports,
(c) maintenance and function testing,
(d) register of inspections and repairs.

This manual is to be submitted for approval.

4.10.2 Documented operating procedures for closing and securing the bow door and inner door are to be kept on board and posted at an appropriate place.

■ *Section 5* Movable decks

5.1 Classification

5.1.1 Movable decks other than those described in *Pt 7, Ch 5, 5.1 Classification 5.1.2* are not a classification item, although consideration must be given to associated supporting structure. Where movable decks are fitted, it is recommended that they be based on the requirements of this Section.

5.1.2 At the Owner's or Builder's request, however, movable decks will be included as a classification item, and the class notation **Movable decks** will be entered in the *Register Book*. In such cases, all movable decks on board the ship are to comply with the requirements of this Section.

5.2 Arrangements and designs

5.2.1 Movable decks are generally to be constructed as pontoons comprising a web structure with top decking. Other forms of construction will be individually considered.

5.2.2 Positive means of control are to be provided to secure decks in the lowered position.

5.2.3 The decks are to be efficiently supported, and hinges, pillars, chains or other means (or a combination of these) are to be designed on the basis of the imposed loads. Where supporting chains and fittings are required, they are to have a factor of safety of at least two on the proof load.

5.2.4 Plans showing the proposed scantlings and arrangements of the system are to be submitted.

5.2.5 Where it is proposed to stow the pontoons on deck, when not in use, details of the proposals for racks, fittings, etc. are to be submitted for consideration.

5.3 Loading

5.3.1 Details of the deck loading resulting from the proposed stowage arrangements of vehicles are to be supplied by the Shipbuilder. These details are to include the axle and wheel spacing, the wheel load, type of tyre and tyre print dimensions for the vehicles. For design purposes the wheel loading is to be taken as not less than 3,0 kN, *see Pt 7, Ch 5, 3 Vehicle decks*.

5.3.2 Where it is proposed also to use the decks for general cargo, the design loadings are to be submitted for consideration.

5.4 Scantling requirements

5.4.1 The scantlings and arrangements of removable decks are to be not less than those required by the Rules for the supporting structure in which the movable decks are fitted. In general the end fixity of primary stiffening members is to be taken as simply supported. Local and secondary stiffening members may be either partially or fully fixed at their end connections dependent upon the proposed arrangement.

5.5 Deflection

5.5.1 Where wheeled vehicles are to be used, the supporting arrangements are to be such that the movement at the edge of one pontoon relative to the next does not exceed 50 mm during loading or unloading operations.

■ *Section 6* Helicopter landing areas

6.1 General

6.1.1 The landing area may be located on an appropriate area of the weather deck or on a platform specifically designed for this purpose and permanently connected to the craft structure.

6.1.2 Attention is drawn to the requirements and guidance of National and other Authorities concerning the construction of helicopter landing platforms and the operation of helicopters as they affect the ship. These include SOLAS Reg.II-2/18 and Reg.III/28 as applicable as well as the *International Chamber of Shipping (ICS) Guide to Helicopter/Ship Operations* and the *International Aeronautical Search and Rescue Manual (IAMSAR)* and *CAP437 Standards for Offshore Helicopter Landing Areas*.

6.1.3 Attention is drawn to the requirements of National and other Authorities concerning the construction of helicopter landing platforms and the operation of helicopters as they affect the craft.

6.1.4 Plans are to be submitted showing the proposed scantlings and arrangements of the structure. The type, size and weight of helicopters to be used are also to be indicated. Details of the helicopter types to be used are to be included in the craft's documentation, and be contained in a notice displayed on the helicopter landing deck.

6.1.5 Where the landing area forms part of a weather or erection deck, the scantlings are to be not less than those required for decks in the same position.

6.1.6 The requirements for fire protection, detection and extinction are outside the scope of classification, and are therefore to comply with requirements of the National Authority.

6.2 Arrangements

6.2.1 The landing area is to be sufficiently large to allow for the landing and manoeuvring of the helicopter, and is to be approached by a clear landing and take-off sector complying in extent with the applicable regulations.

6.2.2 The landing area is to be free of any projections above the level of the deck. Projections in the zone surrounding the landing area are to be kept below the heights permitted by the regulations.

6.2.3 Suitable arrangements are to be made to minimize the risk of personnel or machinery sliding off the landing area. A non-slip surface and anchoring devices, and in the case of independent platforms, safety nets, are to be provided.

6.2.4 Arrangements are to be made for drainage of the platform, including drainage of spilt fuel.

6.2.5 Details of arrangements for securing the helicopter to the deck are to be submitted for approval.

6.3 Landing area plating

6.3.1 The deck plate thickness, t_{p}, within the landing area is to be not less than:

$$t_{\text{p}} = \frac{\alpha s}{1370\sqrt{k_{\text{a}}}}$$

α = thickness coefficient obtained from *Figure 5.3.1 Tyre print chart*

β_p = tyre print coefficient used in *Figure 5.3.1 Tyre print chart*

$$= log_{10}\left(\frac{3,5P_1k_a^{\ 2}}{s^2}\times 10^7\right)$$

where

s and k_a are as defined in *Pt 7, Ch 5, 1.2 Symbols and definitions*.

The plating is to be designed for the emergency landing case taking:

$$P_1 = 2,5\ \varphi_1\ \varphi_2\ \varphi_3 f_\gamma P_w \text{ tonnes}$$

where

φ_1, φ_2, φ_3 are to be determined from *Table 5.3.1 Deck plate thickness calculation*

f = 1,15 for landing decks over manned spaces, e.g. deckhouses, bridges, control rooms, etc.

= 1,0 elsewhere

P_h = the maximum all up weight of the helicopter, in tonnes

P_w = landing load on the tyre print, in tonnes

For helicopters with a single main rotor, P_w is to be taken as P_h divided equally between the two main undercarriage wheels.

For helicopters with tandem main rotors, P_w is to be taken as P_h distributed between all main undercarriage wheels in proportion to the static loads they carry.

For helicopters fitted with landing gear consisting of skids, P_w is to be taken as P_h distributed in accordance with the actual load distribution given by the airframe manufacturer. If this is unknown, P_w is to be taken as 1/6P_h for each of the two forward contact points and 1/3P_h for each of the two aft contact points. The load may be assumed to act as a 300 mm x 10 mm line load at each end of each skid when applying *Figure 5.3.1 Tyre print chart*.

γ = a location factor given in *Table 5.6.1 Location factor, γ*

For wheeled undercarriages, the tyre print dimensions specified by the manufacturer are to be used for the calculation. Where these are unknown it may be assumed that the print area is 300 x 300 mm and this assumption is to be indicated on the submitted plan.

For skids and tyres with an asymmetric print, the print is to be considered oriented both parallel and perpendicular to the longest edge of the plate panel and the greatest corresponding value of α taken from *Figure 5.3.1 Tyre print chart*.

Table 5.6.1 Location factor, γ

Location	γ	
On decks forming part of the hull girder:		
(a) within 0,4L_R amidships	0,71	Values for intermediate locations are to be determined by interpolation
(b) at the F.P. or A.P.	0,6	
Elsewhere	0,6	

6.4 Deck stiffening and supporting structure

6.4.1 The helicopter deck stiffening and the supporting structure are to be designed for the load cases given in *Table 5.6.2 Design load cases for deck stiffening and supporting structure*, with the helicopter being positioned so as to produce the most severe loading condition for each structural member under consideration.

6.4.2 The minimum requirements for section modulus, inertia and web area of secondary stiffeners are to be in accordance with *Table 5.3.3 Secondary stiffener requirements*.

6.4.3 For primary stiffening, and where a grillage arrangement is adopted, it is recommended that direct calculation procedures be used to determine the scantling requirements, in association with the limiting permissible stress criteria given in *Pt 7, Ch 7 Failure Modes Control*. A copy of the calculations is to be submitted for consideration.

Table 5.6.2 Design load cases for deck stiffening and supporting structure

Loadcase	Loads (tonnes)			
	Landing area		Supporting structure (*see* Note 1)	
	UDL, in kN/m^2	Helicopter patch load *see* Note 2	Self weight	Horizontal load, *see* Note 2
(1) Overall distributed loading	2	-	-	-
*(2)*Helicopter emergency landing	0,5	$2{,}5P_{\mathrm{w}} f$	W_{h}	$0{,}5P_{\mathrm{h}}$
(3) Normal Usage	0,5	$1{,}5P_{\mathrm{w}}$	W_{h}	$0{,}5P_{\mathrm{h}} + 0{,}5W_{\mathrm{h}}$
Symbols				
P_{h}, P_{w} and f are as defined in *Pt 7, Ch 5, 6.3 Landing area plating 6.3.1*. UDL = Uniformity distributed vertical load over entire landing area W_{h} = structural self-weight of helicopter platform, in tonnes				
Note 1. For the design of the supporting structure for helicopter platforms applicable self weight and horizontal loads are to be added to the landing area loads. Note 2. The helicopter is to be so positioned as to produce the most severe loading condition for each structural member under consideration.				

■ *Section 7*
Strengthening requirements for navigation in ice conditions

7.1 General

7.1.1 Where an ice class notation is to be included in the class of a craft, the scantlings will require special consideration, *see Pt 3, Ch 2, 9 Navigation in ice*.

7.2 Shell plating

7.2.1 In way of the main ice belt zone, the thickness of the shell plating is to be determined by direct calculation. A copy of these direct calculations is to be submitted for consideration.

7.2.2 Changes in plating thicknesses in the longitudinal direction are to take place gradually.

7.2.3 In general all welded seams and butts in way of the main ice belt are to be dressed smooth.

7.3 Shell framing requirements

7.3.1 The section modulus of an ice framing stiffening member is to be determined by direct calculation. A copy of these direct calculations is to be submitted for consideration.

Section 1 General

1.1 Application

1.1.1 The requirements for longitudinal and transverse global strength for mono-hull and multi-hull craft of aluminium construction, are contained within this Chapter. Due consideration is taken of the dynamic effects, where appropriate, in both the crest and trough wave loading conditions.

1.2 Symbols and definitions

1.2.1 The symbols and definitions applicable to this Chapter are defined below or in the appropriate sub-Section.

L_R = Rule length of the craft, in metres

B = moulded breadth of craft, in metres (to be taken as the breadth of a single hull for multi-hull craft)

l = length of stiffening member, in metres

l_e = effective span length of stiffening member, in metres

p = design pressure as appropriately given in *Pt 3 General Requirements and Constructional Arrangements*, in kN/m^2

s = spacing of stiffener, in mm

t_p = thickness of plating, in mm

σ_a = 0,2 per cent proof stress of the alloy in the welded condition, in N/mm^2

β_a = panel aspect ratio correction, *see Pt 7, Ch 3, 1.15 Aspect ratio correction*

$\tau_a = \dfrac{\sigma_a}{\sqrt{3}}$

1.2.2 The strength deck is to be taken as follows:

(a) Where there is a complete upper deck the strength deck is the upper deck.
(b) Where the upper deck is stepped, as in the case of raised quarterdeck craft, the strength deck is stepped as shown in *Figure 6.1.1 Strength deck*.

1.3 General

1.3.1 The additional pressures arising from the influence of the global loading are considered in the determination of the longitudinal strength requirements for local and secondary stiffening and bottom shell plating.

1.3.2 In general, the effective sectional area of continuous longitudinal strength members, after deduction of openings, is to be used for the calculation of midship section modulus.

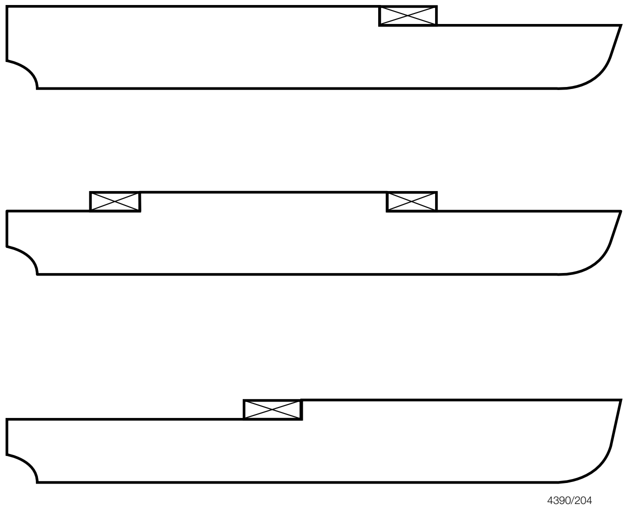


Figure 6.1.1 Strength deck

1.3.3 Structural members which contribute to the overall hull girder strength are to be carefully aligned so as to avoid discontinuities resulting in abrupt variations of stresses and are to be kept clear of any form of openings which may affect their structural performances.

1.3.4 In general, superstructures or deckhouses will not be accepted as contributing to the global longitudinal or transverse strength of the craft. However, where it is proposed to include substantial, continuous stiffening members, special consideration will be given to their inclusion on submission of the designer's/Builder's calculations.

1.3.5 Where continuous deck longitudinals or deck girders are arranged above the strength deck, special consideration may be given to the inclusion of their sectional area in the calculation of the hull section modulus (Z). The lever is to be taken to a position corresponding to the depth of the longitudinal member above the moulded deckline at side amidships. Each such case will be individually considered.

1.3.6 Adequate transition brackets are to be fitted at the ends of effective continuous longitudinal strength members in the deck and bottom structures.

1.3.7 Scantlings of all continuous longitudinal members of the hull girder based on the minimum section stiffness requirements determined from *Pt 7, Ch 6, 2.2 Bending strength* are to be maintained within $0,4L_R$ amidships. However, in special cases, based on consideration of type of craft, hull form and loading conditions, the scantlings may be gradually reduced towards the ends of the $0,4L_R$ part, bearing in mind the desire not to inhibit the craft's loading and operational flexibility.

1.4 Openings

1.4.1 Deck openings having a length in the fore and aft directions exceeding $0,1B$ m or a breadth exceeding $0,05B$ m are in all cases to be deducted from the sectional areas used in the section modulus calculation.

1.4.2 Deck openings smaller than stated in *Pt 7, Ch 6, 1.4 Openings 1.4.1*, including manholes, need not be deducted provided they are isolated and the sum of their breadths or shadow area breadths (*see Pt 7, Ch 6, 1.4 Openings 1.4.3*) in one transverse section does not exceed $0,06\ (B_o - \Sigma b_o)$:

where

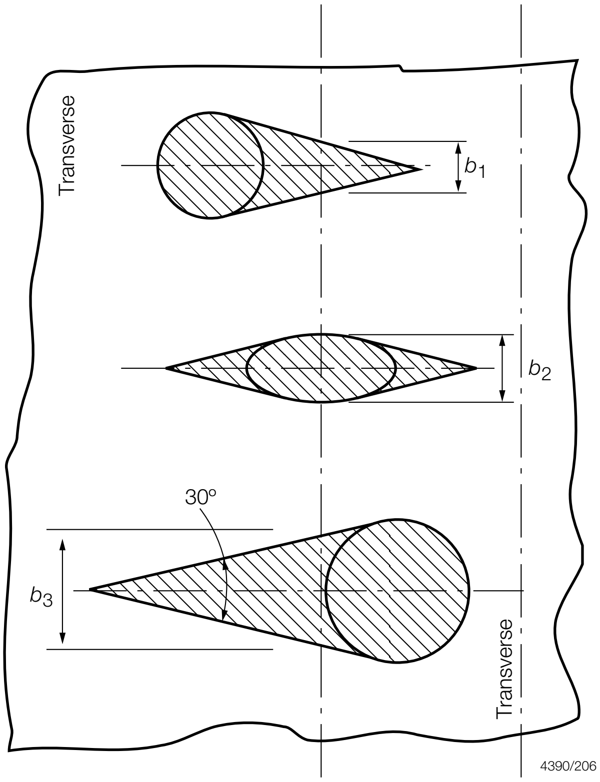
B_o = breadth of craft, in metres, at section considered

Σb_o = sum of breadths, in metres, of deductible openings

Where a large number of deck openings are proposed in any transverse space, special consideration will be required.

1.4.3 Where calculating deduction-free openings, the openings are assumed to have longitudinal extensions as shown by the shaded areas in *Figure 6.1.2 Isolated openings*. The shadow area is obtained by drawing two tangent lines to an opening angle of

30°. The section to be considered is to be perpendicular to the centreline of the ship and is to result in the maximum deduction in each transverse space.



Total equivalent breadth of small openings at xx = b_1 b_2 b_3

Figure 6.1.2 Isolated openings

1.4.4 Isolated openings in longitudinals or longitudinal girders need not be deducted if their depth does not exceed 25 per cent of the web depth or 75 mm, whichever is the lesser.

1.4.5 Openings are considered isolated if they are spaced not less than 1 m apart.

1.4.6 A reduction for drainage holes and scallops in beams and girders, etc. is not necessary so long as the original section stiffness at deck or keel is reduced by no more than three per cent.

1.5 Direct calculation procedure

1.5.1 In direct calculation procedures capable of deriving the wave induced loads on the craft, and hence the required modulus, account is to be taken of the craft's actual form and weight distribution.

1.5.2 Lloyd's Register's (hereinafter referred to as 'LR') direct calculation method involves derivation of response to regular waves by strip theory, short-term response to irregular waves using the sea spectrum concept, and long-term response predictions using statistical distributions of sea states. Other direct calculation methods submitted for approval are normally to contain these three elements and produce similar and consistent results when compared with LR's methods.

1.6 Approved calculation systems

1.6.1 Where the assumptions, method and procedures of a longitudinal strength calculation system have received general approval from LR, calculations using the system for a particular craft may be submitted.

1.7 Information required

1.7.1 In order that an assessment of the longitudinal strength requirements can be made, the following information is to be submitted, in LR's standard format where appropriate:

(a) General arrangement and capacity plan or list, showing details of the volume and position of centre of gravity of all tanks and compartments.
(b) Bonjean data, in the form of tables or curves, for at least 21 equally spaced stations along the hull. A lines plan and/or tables of offsets may also be required.
(c) Details of the calculated lightweight and its distribution.
(d) Details of the weights and centres of gravity of all deadweight items for each of the main loading conditions. It is recommended that this information be submitted in the form of a preliminary Loading Manual, to include the calculated still water and dynamic bending moments and shear forces.

1.8 Loading guidance information

1.8.1 Sufficient information is to be supplied to the Master of every craft to enable him to arrange loading in such a way as to avoid the creation of unacceptable stresses in the craft's structure.

■ *Section 2*
Hull girder strength for mono-hull craft

2.1 General

2.1.1 Longitudinal strength calculations are to be submitted for all craft with a Rule length, L_R, exceeding 45 m covering the range of load and ballast conditions proposed, in order to determine the required hull girder strength. Still water, static wave and dynamic bending moments and shear forces are to be calculated for both departure and arrival conditions.

2.1.2 For craft of ordinary hull form with a Rule length, L_R, less than 45 m, the minimum hull girder strength requirements are generally satisfied by scantlings obtained from local strength requirements. However longitudinal strength calculations may be required at LR's discretion, dependent upon the form, constructional arrangement and proposed loading.

2.1.3 Where the Rule length, L_R, of the craft exceeds 75 m, or for new designs of large, structurally complicated craft, the design loads and scantling determination formulae in this Chapter are to be supplemented by direct calculation and structural analysis by 3-D finite element methods. These supplementary calculations are to include the results of model tests and full scale measurement where available or required by LR. Full details of such methods and all assumptions and calculations, which are to be based on generally accepted theories, are to be submitted for appraisal.

2.2 Bending strength

2.2.1 The effective geometric properties of the midship section are to be calculated directly from the dimensions of the section using only the effective material elements which contribute to the global longitudinal strength. For the purposes of this analysis an element may be of deck plating, longitudinal girder, inner bottom, etc. or other continuous member.

2.2.2 The longitudinal strength of craft $\frac{V}{\sqrt{L_{WL}}} \geq 3,0$ is to satisfy both the following criteria:

$$\sigma_k + \sigma_l + \sigma_t < 1,2\,\sigma_p$$

$$\sigma_d < \sigma_p$$

where

σ_p = maximum permissible hull vertical bending stress, in N/mm^2

= $f_{\sigma gH}\sigma_a$

$f_{\sigma gH}$ = limiting hull bending stress coefficient taken from *Table 7.3.2 Limiting stress coefficients for global loading* in Chapter 7

L_{WL} is as defined in *Pt 3, Ch 1, 6.2 Principal particulars 6.2.5*

σ_k, σ_l, σ_t and σ_d are given in *Table 6.2.1 Longitudinal component stresses*

σ_a is as defined in *Pt 7, Ch 6, 1.2 Symbols and definitions 1.2.1*.

Table 6.2.1 Longitudinal component stresses

Component stress type	Nominal stress (N/mm^2)
Hull girder bending stress at strength deck amidships	$\sigma_d = \dfrac{M_R}{1000 Z_d}$
Hull girder bending stress at keel amidships	$\sigma_k = \dfrac{M_R}{1000 Z_k}$
Actual stress in bottom longitudinals amidships due to design pressure load	$\sigma_l = \dfrac{p_s s l_e^2}{12 Z_l}$
Actual stress in bottom plating amidships due to design pressure load	$\sigma_t = 0,34 P_t \left(\dfrac{\beta s}{t_p}\right)^2 \times 10^{-3}$
Symbols and definitions	
M_R = design longitudinal midship bending moment, in kNm, given in *Pt 5, Ch 5, 5 Design criteria and load combinations* p_s = additional effective pressure loading, in kN/m^2, on bottom longitudinals from global dynamic load model, given in *Pt 5, Ch 5, 2.6 Dynamic bending moments and associated shear forces 2.6.3* P_t = additional effective pressure loading, in kN/m^2, on bottom plating from global dynamic load model, given in *Pt 5, Ch 5, 2.6 Dynamic bending moments and associated shear forces 2.6.4* Z_d = actual section modulus at deck, in m^3 Z_k = actual section modulus at keel, in m^3 Z_l = maximum section modulus of bottom longitudinal stiffener, associated with plating, amidships, in cm^3 s, l_e, β and t_p are as defined in *Pt 7, Ch 6, 1.2 Symbols and definitions*.	

2.2.3 The longitudinal strength of craft $\dfrac{V}{\sqrt{L_{WL}}} < 3,0$ is to satisfy both the following criteria:

$$\sigma_k < \sigma_p$$
$$\sigma_d < \sigma_p$$

where σ_p is as defined in *Pt 7, Ch 6, 2.2 Bending strength 2.2.2*.

σ_k and σ_d, are given in Table 6.2.1

L_{WL} is as defined in *Pt 3, Ch 1, 6.2 Principal particulars 6.2.5*.

2.3 Shear strength

2.3.1 The shear strength of the craft at any position along its length is to satisfy the following criterion:

$$\frac{Q_R}{A_\tau} 10^{-3} \le \tau_p$$

where

Q_R = design hull shear force at any section along the hull length, L_R, in kN determined from *Pt 5, Ch 5, 5 Design criteria and load combinations*

A_τ = shear area of transverse section, in m^2, is to be taken as the effective net sectional area of the shell plating and longitudinal bulkheads after deductions for openings. For longitudinal strength members which are inclined to the vertical, the area of the member to be included in the calculation is to be based on the area projected onto the vertical plane, *see Figure 6.2.1 Effective shear area*

τ_p = maximum permissible mean shear stress, in N/mm^2

= $f_{\sigma g} \tau_a$

$f_{\sigma g}$ = limiting hull shear stress coefficient taken from *Table 7.3.2 Limiting stress coefficients for global loading*

τ_a is as defined in *Pt 7, Ch 6, 1.2 Symbols and definitions 1.2.1*.

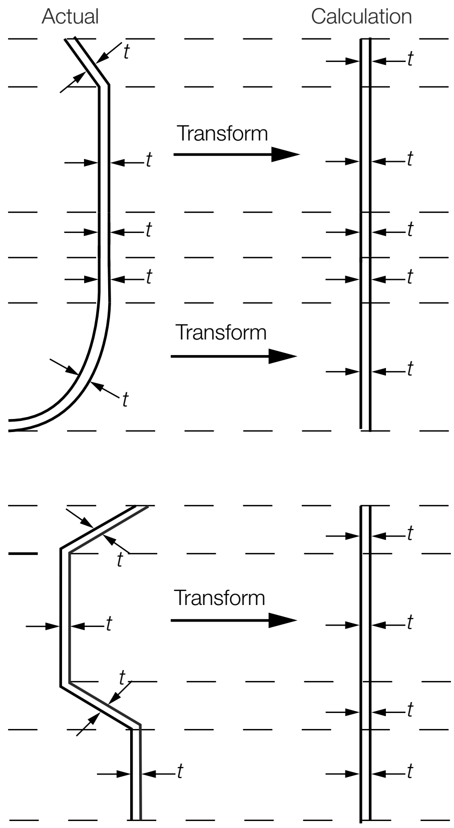


Figure 6.2.1 Effective shear area

2.4 Torsional strength

2.4.1 Torsional stresses are typically small for mono-hulls of ordinary form of Rule length, L_R, less than 75 m and can generally be ignored.

2.4.2 The calculation of torsional stresses and/or deflections may be required when considering craft with large deck openings, unusual form or proportions. Calculations may in general be required to be carried out using a direct calculation procedure. Such calculations are to be submitted in accordance with *Pt 7, Ch 6, 1.5 Direct calculation procedure*.

2.5 Superstructures global strength

2.5.1 Where the side walls of superstructures are aligned with the side shell, and these side walls are fully plated with scantlings as for side shell, the effect of the superstructure in global strength can be estimated from *Pt 7, Ch 6, 2.5 Superstructures global strength 2.5.2* to *Pt 7, Ch 6, 2.5 Superstructures global strength 2.5.6*. In case there are openings in the side walls that would affect the connection of the superstructure deck with the hull, or when the side walls are not in-line with the side shell, the effectiveness of the superstructure in global strength is to be determined by direct calculation.

The effectiveness of the superstructure in absorbing hull girder bending loads is to be established where the first tier of the superstructure extends within 0,4*L* amidship and where:

$$l_{\rm d} > b_{\rm d} + 3h_{\rm d}$$

where

$l_{\rm d}$ = length of first tier, in metres

$b_{\rm d}$ = breadth of first tier, in metres

$h_{\rm d}$ = 'tween deck height of first tier, in metres

2.5.2 For superstructures with one or two tiers extending outboard to the craft's side shell, the effectiveness in absorbing hull girder bending loads in the uppermost effective tier may be assessed by the following factor:

$$\eta_s = 7\big[(\varepsilon - 5)\gamma^4 + 94(5 - \varepsilon)\gamma^3 + 2800(\varepsilon - 5,8)\gamma^2 + 27660(9 - \varepsilon)\gamma\big] f(\lambda, N) \times 10^{-7}$$

where

$f(\lambda, N=1)$ = 1

$f(\lambda, N=2)$ = $0,90\lambda^3 - 2,17\lambda^2 + 1,73\lambda + 0,50$

and

N = 1 if $l_2 < 0,7\, l_1$

= 2 if $l_2 \geq 0,7\, l_1$

λ = $\dfrac{l_{\rm w}}{L_{\rm R}}$ or 1, whichever is less

ε = $\dfrac{b_1}{h_1}$ or 5, whichever is less

γ = $\dfrac{l_{\rm w}}{h_1}$ or 25, whichever is less

$l_{\rm w}$ = l_1 for N = 1

= $\dfrac{(2l_1 + l_2)}{3}$ for N = 2

$L_{\rm R}$ = is as defined in *Pt 7, Ch 6, 1.2 Symbols and definitions 1.2.1*, in metres

l_1, b_1, h_1 = is as defined in *Pt 7, Ch 6, 2.5 Superstructures global strength 2.5.1*, in metres

l_2 = length of second tier, in metres.

2.5.3 The hull girder compressive bending stress $\sigma_{\rm L}$, in the uppermost effective tier at side may be derived according to the following formula:

$$\sigma_{\rm L} = \eta_{\rm s}\frac{M_{\rm R}}{1000 Z_{100}}\ {\rm N/mm^2}$$

where

M_R = hull girder bending moment at midships due to sagging as determined in *Pt 5, Ch 5, 5 Design criteria and load combinations*, in kNm

Z_{100} = section modulus at uppermost effective tier of hull and effective tiers, assuming tiers to be 100 per cent effective, in m^3

η_s = as defined in *Pt 7, Ch 6, 2.5 Superstructures global strength 2.5.2*

2.5.4 The compressive stress, σ_L, in the uppermost effective tier at side is to be checked against buckling in accordance with *Pt 7, Ch 7, 4 Buckling control*.

2.5.5 The uppermost effective tier may need to fulfil the requirements for strength deck when the following applies:

$$\eta_s = \left(1 + \frac{Z_0 h}{I_{100}}\right)^{-1}$$

where

η_s = as defined in *Pt 7, Ch 6, 2.5 Superstructures global strength 2.5.2*

Z_0 = section modulus of hull only at hull upper deck, in m^3

I_{100} = moment of inertia of hull and effective tiers, assuming tiers to be 100 per cent effective, in m^4

h = height from hull upper deck to uppermost effective tier, in metres.

2.5.6 The deformation of large openings in side walls of superstructures is to be investigated. They shall not exceed the deformation limit of the closing appliances.

■ *Section 3*
Additional hull girder strength requirements for multi-hull craft

3.1 General

3.1.1 Except as otherwise specified within this Section, the global strength requirements for multi-hull craft are to comply with *Pt 7, Ch 6, 2 Hull girder strength for mono-hull craft*.

3.1.2 Longitudinal strength calculations are to be submitted for all craft with a Rule length, L_R, exceeding 40 m covering the range of load and ballast conditions proposed, in order to determine the required hull girder strength. Still water, static wave and dynamic bending moments and shear forces are to be calculated for both departure and arrival conditions.

3.1.3 For craft of ordinary hull form length with a Rule length, L_R, less than 40 m the minimum hull girder strength requirements are generally satisfied by scantlings obtained from local strength requirements. However longitudinal strength calculations may be required at LR's discretion, dependent upon the proposed loading.

3.1.4 Where the Rule length, L_R, of the craft exceeds 60 m, or for new designs of large, structurally complicated craft, the design loads and scantling determination formulae in this Chapter are to be supplemented by direct calculation and structural analysis by 3-D finite element methods. These supplementary calculations are to include the results of model tests and full scale measurement where available or required by LR. Full details of such methods and all assumptions and calculations, which are to be based on generally accepted theories, are to be submitted for appraisal.

3.1.5 The strength deck plating in way of the cross-deck structure, the wet-deck plating, longitudinal bulkheads and girders, and other continuous members may be included in the determination of the midship section stiffness.

3.1.6 Special consideration will be given to the global strength requirements for craft with more than two hulls linked by cross-deck structure.

3.2 Hull longitudinal bending strength

3.2.1 The requirements of *Pt 7, Ch 6, 2.2 Bending strength* are in general to be complied with, using the appropriate design bending moment and effective pressure loadings applicable to multi-hull craft, as determined from *Pt 5, Ch 5, 5 Design criteria and load combinations*.

3.3 Hull shear strength

3.3.1 The requirements of *Pt 7, Ch 6, 2.3 Shear strength* are to be complied with so far as they are applicable.

3.4 Torsional strength

3.4.1 Where a craft is of unusual form or novel construction, or at the discretion of LR, the torsional stress is to be determined by direct calculation methods using the twin hull torsional connecting moment as defined in *Pt 5, Ch 5, 5 Design criteria and load combinations*. Such calculations are to be submitted in accordance with *Pt 7, Ch 6, 1.5 Direct calculation procedure*.

3.5 Strength of cross-deck structures

3.5.1 Design loads to be applied for scantling calculations are transverse vertical bending moment and shear force, twin hull torsional connecting moment, external pressure load and appropriate internal loads as defined in *Pt 5 Design and Load Criteria*.

3.5.2 The primary stiffening members of the cross-deck structure are to provide sufficient strength to satisfy the stress criteria given in *Table 6.3.1 Primary member stress criteria*.

3.5.3 The component nominal stresses may be determined in accordance with *Table 6.3.2 Cross-deck component stresses for designs complying with 3.5.3* in the case where the cross-deck is formed by transverse primary stiffeners or bulkheads and the following assumptions are taken:

(a) The cross-deck is symmetrical forward and aft of a transverse axis at its half length.
(b) Primary stiffeners having the same scantlings and spacing.

3.5.4 Other cross-deck designs subjected to global transverse loads will require a two-dimensional grillage analysis to be performed to demonstrate compliance with *Pt 7, Ch 6, 3.5 Strength of cross-deck structures 3.5.2*.

3.5.5 Section properties are to be calculated using an effective breadth of plating to be determined in accordance with *Pt 7, Ch 3, 1.11 Effective width of attached plating*.

3.5.6 Where primary stiffening members support areas of plating of the extruded plank type, or the floating frame system is used, the effect of the plating attached to the secondary stiffening members is to be ignored when determining the global section modulus requirements.

Table 6.3.1 Primary member stress criteria

Stress type	Component stresses	Allowable stress level (N/mm^2)
Total direct stress, σ_P	$\sigma_P = \sigma_{MB} + \sigma_{MT} + \sigma_d$	$f_{\sigma gV}\sigma_a$
Total shear stress, τ_P	$\tau_P = \tau_T + \tau_{MBT} + \tau_{MT}$	$f_{\tau gV}\ \tau_a$
Equivalent stress, σ_{eq}	$\sigma_{eq} = \sqrt{\sigma^2 + 3\tau^2}$	1,2 $f_{\sigma eg}\sigma_a$
Symbols and definitions		
σ_{MB}, σ_{MT}, τ_T, τ_{MBT}, τ_{MT} are component stresses, in N/mm^2, to be taken from *Table 6.3.2 Cross-deck component stresses for designs complying with 3.5.3*. $f_{\sigma gV}$, $f_{\tau gV}$ and $f_{\sigma eg}$ are limiting stress coefficients for cross-deck structures to be taken from *Table 7.3.2 Limiting stress coefficients for global loading* in Chapter 7. σ_a and $\tau_a$are defined in*Pt 7, Ch 6, 3.1 General 3.1.2*		

Table 6.3.2 Cross-deck component stresses for designs complying with 3.5.3

Component stress type	Nominal stress (N/mm^2)
Hull girder bending stress at strength deck amidships, *see Table 6.2.1 Longitudinal component stresses*	$\sigma_{d} = f_{MR}\frac{M_{R}}{1000Z_{d}}$
Stress induced by the transverse bending moment M_{B}, as defined in *Pt 5, Ch 5, 5 Design criteria and load combinations*	$\sigma_{MB} = f_{MB}\frac{M_{B}}{n_{Z}}10^{3}$
Stress induced by the torsional moment M_{T}, as defined in *Pt 5, Ch 5, 5 Design criteria and load combinations*	$\sigma_{MT} = f_{MT}\frac{3x_{H}M_{T}}{n(n+1)s_{p}Z}10^{3}$
Shear stress induced by the vertical shear force Q_{T}, as defined in *Pt 5, Ch 5, 5 Design criteria and load combinations*	$\tau_{T} = f_{MB}\frac{5Q_{T}}{nA_{w}}$
Bending shear stress induced by the torsional moment M_{T}, as defined in *Pt 5, Ch 5, 5 Design criteria and load combinations*	$\tau_{MBT} = f_{MT}\frac{60M_{T}}{n(n+1)s_{p}A_{w}}$
Shear stress induced by the torsional moment M_{T}, as defined in *Pt 5, Ch 5, 5 Design criteria and load combinations*	$\tau_{MT} = f_{MT}\frac{46\,\kappa\,x_{H}^{2}M_{T}}{n\left(n^{2}+1\right)s_{p}^{2}I_{y}}10^{3}$

Symbols and definitions

Q_{T} = vertical shear force, in kN, as determined from, *Pt 5, Ch 5, 5 Design criteria and load combinations*

M_{B} = transverse bending moment in kNm, as determined from *Pt 5, Ch 5, 5 Design criteria and load combinations*

M_{T} = torsional moment in kNm, as determined from *Pt 5, Ch 5, 5 Design criteria and load combinations*

n = total number of transverse primary stiffeners or bulkheads

A_{w} = stiffener web area, cm^2

Z = primary stiffeners sections section modulus, in cm^3

s_{p} = stiffener spacing, in metres

I_{y} = moment of inertia of stiffener, cm^4

x_{H} = transverse distance between the centre of the two hulls, in metres

κ = t_{f}, for symmetrical I-section, in mm

= $b_{b}h/(b_{b}+h)$, for constant thickness box sections, in mm

σ_{MB} = stress induced by the transverse bending moment M_{B}, as defined in *Pt 5, Ch 5, 5 Design criteria and load combinations*, in N/mm^2

σ_{MT} = stress induced by the torsional moment M_{T}, as defined in *Pt 5, Ch 5, 5 Design criteria and load combinations*, in N/mm^2

τ_T = shear stress induced by the vertical shear force Q_T, as defined in *Pt 5, Ch 5, 5 Design criteria and load combinations*, in N/mm^2

τ_{MBT} = bending shear stress induced by the torsional moment M_T, as defined in *Pt 5, Ch 5, 5 Design criteria and load combinations*, in N/mm^2

τ_{MT} = shear stress induced by the torsional moment M_T, as defined in *Pt 5, Ch 5, 5 Design criteria and load combinations*, in N/mm^2

t_f = face plate thickness, in mm

b_b = breadth of box section, in mm

h_b = height of box section, in mm

f_{MR}, f_{MB} and f_{MT} are load combination factors reflecting the portions of each component global design load, M_R, Q_T, M_B and M_T, corresponding to the most severe load combinations. The most severe load combinations are the combinations of loads resulting in the maximum bending, shear and effective stress, respectively. The assessment of these load combinations need to take due consideration for the component load magnitude variation with wave heading and also the phasing in time between them. Generally, f_{MR}, f_{MB} and f_{MT} are to be taken as indicated in *Table 6.3.3 Load combination factors*.

Table 6.3.3 Load combination factors

Heading	Factors		
	f_{MB}	f_{MR}	f_{MT}
Head sea	0,1	1,0	0,1
Beam sea	1,0	0,1	0,2
Quartering sea	0,1	0,4	1,0

3.6 Grillage structures

3.6.1 For complex girder systems, a complete structural analysis using numerical methods may be required to be performed to demonstrate that the stress levels are acceptable when subjected to the most severe and realistic combination of loading conditions intended.

3.6.2 In general, the transverse and vertical girders, bottom and side structures, bridge structure, deck structures and any other parts of the craft which LR considers critical to the craft's structural integrity are to be included in the numerical modelling of the craft.

3.7 Analysis techniques

3.7.1 General or special purpose computer programs or any other analytical techniques may be used provided that the effects of bending, shear, axial and torsion are properly accounted for and the theory and idealisation used can be justified.

3.7.2 In general, grillages consisting of slender girders may be idealised as frames based on beam theory provided proper account of the variations of geometric properties is taken. For cases where such an assumption is not applicable, finite element analysis or equivalent methods may have to be used.

3.7.3 Analysis of the cross deck structures with regard to impact loads due to slamming may have to be carried out using advanced structural analysis techniques.

Section

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull and multi-hull craft of aluminium construction as defined in *Ch 1, 1 Background*.

1.2 General

1.2.1 The failure modes criteria contained within this Chapter are to be used in the formulae from the preceding Chapters to determine the scantling requirements. In addition, they are to be used when direct calculation methods are proposed as an alternative.

1.3 Symbols and definitions

1.3.1 The symbols and definitions applicable to this Chapter are defined in the appropriate Sections.

1.3.2 The slamming zone area referred to in this Chapter is defined as the region where the operational non-displacement mode pressures exceed the operational displacement mode pressures.

1.4 Direct calculations

1.4.1 Where direct calculations are proposed, the requirements of *Pt 3, Ch 1, 2 Direct calculations* are to be complied with.

1.4.2 In addition, with the agreement of Lloyd's Register (hereinafter referred to as 'LR'), tests may be conducted to demonstrate the actual response of the structure and the results verified against the failure mode criteria in this Chapter.

■ *Section 2* Deflection control

2.1 General

2.1.1 The limiting deflection requirements for plate panels and stiffening members are given in terms of limiting deflection coefficient, f_{δ}, *see Table 7.2.1 Limiting deflection ratio*. The coefficient equates to a span/deflection ratio in consistent units.

Table 7.2.1 Limiting deflection ratio

Item	Deflection ratios, f_{δ}
Bottom structure:	
• secondary stiffening	475
• primary girders and web frames	625
Side structure:	
• secondary stiffening	475
• primary girders and web frames	625
Main/strength deck structures:	
• secondary stiffening	625
• primary girders and web frames	775
• hatch covers	775
Superstructures/deckhouses stiffeners:	
(a) Generally: • secondary	400
• primary	475
(b) Coachroof: • secondary	475
• primary	625
(c) House top: • secondary	400
• primary	400
Lower/inner decks and house top, subject to personnel loading:	
• secondary members	475
• primary members	625
Deep tank stiffeners:	
• secondary members	625
• primary members	775
Watertight bulkhead stiffeners:	
• secondary members	400
• primary members	475
Multi-hull cross-deck stiffeners:	
• secondary members	475
• primary members	625
Vehicle deck stiffeners:	
• secondary members	625
• primary members	775
Helicopter/flight deck stiffeners:	

• secondary members	625
• primary members	775
Note Where significant curvature exists over the span of the stiffener or breadth of the panel, the allowable deflections will be specially considered.	

Section 3
Stress control

3.1 General

3.1.1 The nominal limiting stress requirements for plating and primary and secondary stiffening members subject to local loading conditions are given in terms of limiting stress coefficients, *see Table 7.3.1 Limiting stress coefficients for local loading*. The coefficients are expressed as a proportion of the 0,2 per cent proof stress of the material.

3.1.2 The limiting stress coefficients for structural elements subject to global loading conditions are given in *Table 7.3.2 Limiting stress coefficients for global loading*.

3.1.3 In the determination of the magnitude of the equivalent stress, σ_{eq}, it is assumed that the stresses are combined using the following formula:

$$\sigma_{eq} = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x \sigma_y + 3\tau^2}$$

where

σ_x = direct stress in the x direction

σ_y = direct stress in the y direction

τ = shear stress in the xy plane

Table 7.3.1 Limiting stress coefficients for local loading

Item		Limiting stress coefficient		
		Bending f_σ	Shear f_τ	Equivalent f_e
Shell envelope:				
(a) Bottom shell plating:	• slamming zone	0,85	-	-
	• elsewhere	0,75	-	-
(b) Side shell plating:	• slamming zone	0,85	-	-
	• elsewhere	0,75	-	-
(c) Keel		0,75	-	-
Bottom structure:				
(a) Secondary stiffening:	• slamming zone	0,75	0,75	-
	• elsewhere	0,65	0,65	-
(b) Primary girders and web frames		0,65	0,65	0,75
(c) Engine girders		0,55	0,55	0,75

Side structure:				
(a) Secondary stiffening:	• slamming zone	0,75	0,75	-
	• elsewhere	0,65	0,65	-
(b) Primary girders and web frames		0,65	0,65	0,75
Bow doors:				
(a) Plating		0,65	-	-
(b) Secondary stiffening		0,51	0,433	-
(c) Primary stiffening		0,51	0,34	0,64
Main/strength deck plating and stiffeners:				
(a) Plating		0,75	-	-
(b) Secondary stiffening		0,65	0,65	-
(c) Primary girders and web frame		0,65	0,65	0,75
(d) Hatch covers		0,55	0,55	0,64
Superstructures/deckhouses:				
(a) Deckhouse front, 1st tier:	• plating	0,65	-	-
	• stiffening	0,60	0,60	-
(b) Deckhouse front upper tiers:	• plating	0,75	-	-
	• stiffening	0,65	0,65	-
(c) Deckhouse aft and sides:	• plating	0,75	-	-
	• stiffening	0,75	0,75	-
(d) Coachroof:	• plating	0,65	-	-
	• stiffening	0,65	0,65	-
(e) House top:	• plating	0,75	-	-
	• stiffening	0,75	0,75	-
(f) Lower/inner decks and house top subject to personnel loading:	• plating	0,75	-	-
	• stiffening	0,60	0,60	-
Bulkheads:				
(a) Watertight bulkhead:	• plating	1,0	-	-
	• secondary stiffening	0,95	0,95	-
	• primary stiffening	0,90	0,90	1,0
(b) Watertight bulkhead doors		0,825	0,825	0,825
(c) Structure supporting watertight doors		0,80	0,80	-
(d) Minor bulkheads:	• plating	0,65	-	-

	• secondary stiffening	0,65	0,65	-
	• primary stiffening	0,65	0,65	0,75
(e) Deep tank bulkheads:	• plating	0,65	-	-
	• secondary stiffening	0,65	0,65	-
	• primary stiffening	0,75	0,75	-
Multi-hull cross-deck structure:				
(a) Plating:	• slamming zone	0,85	-	-
	• elsewhere	0,75	-	-
(b) Secondary stiffening:	• slamming zone	0,75	0,75	-
	• elsewhere	0,65	0,65	-
(c) Primary stiffening		0,65	0,65	0,75
Vehicle deck:				
(a) Plating		0,60	-	-
(b) Secondary stiffening		0,425	0,425	-
(c) Primary stiffening		0,525	0,525	0,75
Helicopter/flight decks:				
(a) Normal usage:	• plating	0,65	-	-
	• secondary stiffening	0,75	0,75	-
	• primary stiffening	0,625	0,625	0,60
(b) Emergency landing:	• plating	0,75	-	-
	• secondary stiffening	1,0	1,0	-
	• primary stiffening	0,825	0,825	0,9
(c) Crane pedestal/foundation structural elements		0,7	0,7	0,75
Definitions				
The slamming zone is the region where the operational non-displacement mode pressures exceed the operational displacement mode pressures, *see Pt 7, Ch 7, 1.3 Symbols and definitions 1.3.2*.				

Table 7.3.2 Limiting stress coefficients for global loading

Operational mode of craft	Limiting stress coefficient					
	Hull girder			Cross-deck		
	Bending $f_{\sigma gH}$	Shear $f_{\tau gH}$	Equivalent $f_{\sigma eg}$	Bending $f_{\sigma gV}$	Shear $f_{\tau gV}$	Equivalent $f_{\sigma eg}$
$\Gamma \geq 3{,}0$ or $\Delta \leq 0{,}04(L_R B)^{1{,}5}$	0,80	0,80	0,825	0,80	0,80	0,825

$\Gamma < 3{,}0$ and $\Delta > 0{,}04(L_R B)^{1,5}$	0,72	0,72	0,75	0,72	0,72	0,75
Symbols						
$f_{\sigma gH}$ = limiting hull bending stress coefficient. $f_{\tau gH}$ = limiting hull shear stress coefficient. $f_{\sigma gV}$ = limiting cross-deck bending stress coefficient. $f_{\tau gV}$ = limiting cross-deck shear stress coefficient. $f_{\sigma eg}$ = limiting equivalent stress coefficient. Γ = is the Taylor Quotient as defined in *Pt 5, Ch 2, 2.1 Parameters to be used for the determination of load and design criteria 2.1.16* Δ = is the displacement as defined in *Pt 5, Ch 2, 2.1 Parameters to be used for the determination of load and design criteria 2.1.16* L_R and B = are as defined in *Pt 3, Ch 1, 6.2 Principal particulars*						

■ *Section 4* Buckling control

4.1 General

4.1.1 This Section contains the requirements for buckling control of plate panels subject to in-plane compressive and/or shear stresses and buckling control of primary and secondary stiffening members subject to axial compressive and shear stresses.

4.1.2 The requirement for buckling control of plate panels are contained in *Pt 7, Ch 7, 4.3 Plate panel buckling requirements* to *Pt 7, Ch 7, 4.6 Shear buckling of stiffened panels*. The requirements for secondary stiffening members are contained in *Pt 7, Ch 7, 4.7 Secondary stiffening in direction of compression*to *Pt 7, Ch 7, 4.8 Secondary stiffening perpendicular to direction of compression*. The requirements for primary members are contained in *Pt 7, Ch 7, 4.9 Buckling of primary members* and *Pt 7, Ch 7, 4.10 Shear buckling of girder webs*.

4.1.3 In general all areas of the structure are to meet the buckling strength requirements for the design stresses. The design stresses are to be taken as follows:

(a) Global hull girder bending and shear stresses given in Chapter 6, but not including stresses σl and σt as defined in *Table 6.2.1 Longitudinal component stresses* in *Pt 7, Ch 6 Hull Girder Strength*.
(b) Stresses from local compressive loads.

4.1.4 The buckling requirements are to be met using the net scantlings, hence any additional thickness for corrosion margin or Owners' extra is not included in scantlings used to assess the buckling performance.

4.2 Symbols

4.2.1 The symbols used in this Section are defined below and in the appropriate sub-Section:

t_p = thickness of plating, in mm

A_R = panel aspect ratio

$= \dfrac{a}{b}$

a = panel length, i.e. parallel to direction of compressive stress being considered, in mm

b = panel breadth, i.e. perpendicular to direction of compressive stress being considered, in mm

S_p = span of primary members, in metres

σ_a = 0,2 per cent proof stress of the material, in N/mm^2

σ_e = elastic compressive buckling stress, in N/mm^2

σ_c = critical compressive buckling stress, including the effects of plasticity where appropriate, in N/mm^2

τ_a = specified minimum yield shear stress the of material, in N/mm^2

= $\dfrac{\sigma_a}{\sqrt{3}}$ N/mm^2

E = modulus of elasticity of material, in N/mm^2

τ_e = elastic shear buckling stress, in N/mm^2

τ_c = critical shear buckling stress, in N/mm^2

b_{eb} = lesser of $1{,}9 t_p \sqrt{\dfrac{E}{\sigma_a}}$ or 0,8b mm

A_{te} = cross-sectional area of secondary stiffener, in cm^2, including an effective breadth of attached plating, b_{eb}

s = length of shorter edge of plate panel, in mm (typically the spacing of secondary stiffeners)

l = length of longer edge of plate panel, in metres

S = spacing of primary member, in metres (measured in direction of compression)

4.3 Plate panel buckling requirements

4.3.1 This Section gives methods for evaluating the buckling strength of plate panels subjected to the following load fields:

(a) uni-axial compressive loads;
(b) shear loads;
(c) bi-axial compressive loads;
(d) uni-axial compressive loads and shear loads;
(e) bi-axial compressive loads and shear loads.

4.3.2 The plate panel buckling requirements will be satisfied if the buckling interaction equations given in *Table 7.4.2 Plate panel buckling requirements* for the above load fields are complied with.

4.3.3 The critical compressive buckling stresses and critical shear buckling stresses required for *Table 7.4.2 Plate panel buckling requirements* are to be derived in accordance with *Pt 7, Ch 4, 4.4 Bottom outboard transverse stiffeners*.

4.3.4 The buckling factors of safety λ_s and λ_t required by *Table 7.4.2 Plate panel buckling requirements* are given in *Table 7.4.4 Buckling factor of safety* for the structural member concerned.

4.3.5 For all structural members which contribute to the hull girder strength, the plate panel buckling requirements for uni-axial compressive loads, *Table 7.4.2 Plate panel buckling requirements*, and shear loads, *Table 7.4.2 Plate panel buckling requirements* are to be complied with.

4.3.6 In addition to *Pt 7, Ch 7, 4.3 Plate panel buckling requirements 4.3.5*, structural members which are subjected to local compressive loads and/or shear loads are to be verified using the plate panel buckling requirements in *Table 7.4.2 Plate panel buckling requirements*.

4.3.7 However, where some members of the structure have been designed such that elastic buckling of the plate panel between the stiffeners is allowable, then the requirements of *Pt 7, Ch 7, 4.5 Additional requirements for plate panels which buckle elastically* must be applied to the buckling analysis of the stiffeners supporting the plating. In addition, panels which do not satisfy the panel buckling requirements must be indicated on the appropriate drawing and the effect of these panels not being effective in transmitting compressive loads taken into account for the hull girder strength calculation.

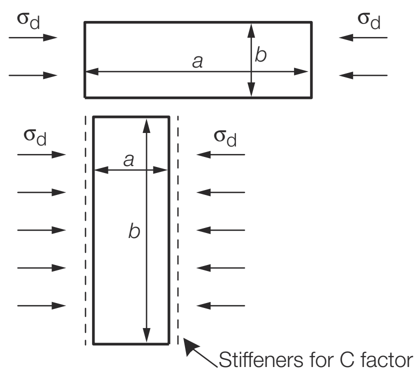
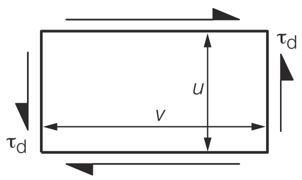
4.3.8 In general the plate panel buckling requirements for more complex load fields, *see Pt 7, Ch 7, 4.3 Plate panel buckling requirements 4.3.1.(c)*, *Pt 7, Ch 7, 4.3 Plate panel buckling requirements 4.3.1.(d)*, *Pt 7, Ch 7, 4.3 Plate panel buckling requirements 4.3.1.(e)*, are to be complied with. Where this is not possible, due to elastic buckling of the panel, then the critical buckling stress, σ_c, may be based on the ultimate collapse strength of the plating, σ_u from *Pt 7, Ch 7, 4.5 Additional requirements for plate panels which buckle elastically 4.5.4*, instead of the elastic buckling stress, σ_e, derived in *Pt 7, Ch 7, 4.3 Plate panel buckling requirements 4.3.5*. In addition, the requirements of *Pt 7, Ch 7, 4.5 Additional requirements for plate panels which buckle elastically* are to be met for the supporting secondary stiffeners and primary members.

4.4 Derivation of the buckling stress for plate panels

4.4.1 The critical compressive buckling stress, σ_c, and elastic buckling stress, σ_e, for a plate panel subjected to uni-axial in-plane compressive loads are to be derived in accordance with *Table 7.4.1 Buckling stress of plate panels*.

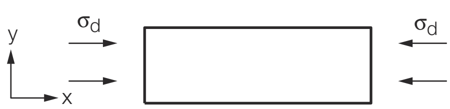
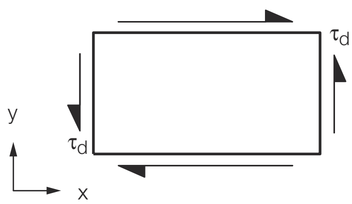
4.4.2 The critical shear buckling stress, τ_c, for a plate panel subjected to pure in-plane shear load is to be derived in accordance with *Table 7.4.1 Buckling stress of plate panels*.

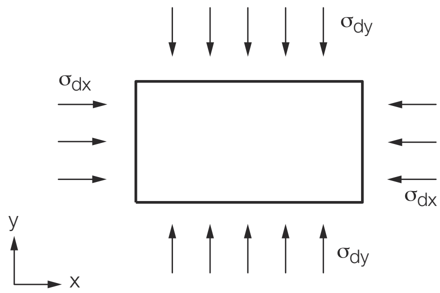
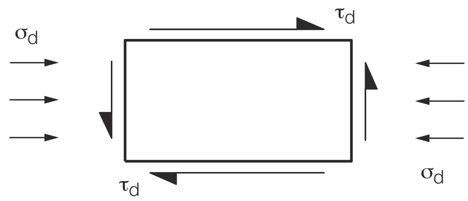
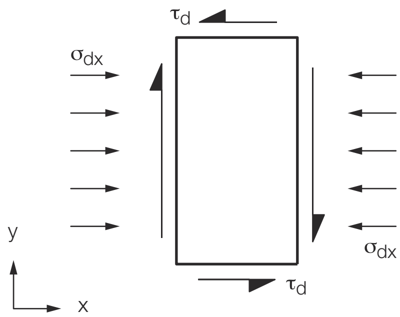
Table 7.4.1 Buckling stress of plate panels

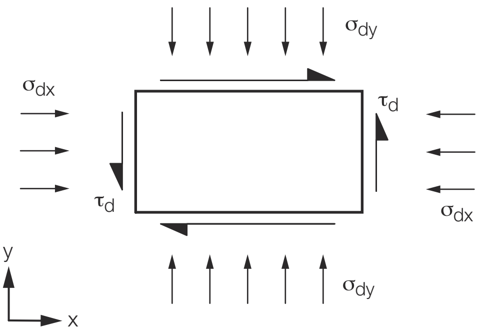
Mode	Elastic buckling stress, N/mm^2, *see* Note	
(a) Uni-axial compression: *(i)* Long narrow panels, loaded on the narrow edge *(ii)* Short broad panels, loaded on the broad edge	$A_R \geq 1$ $\sigma_e = 3,62\,\varphi\,E\left(\frac{t_p}{b}\right)^2$ $A_R < 1$ $\sigma_e = 0,9C\,\varphi\left(\frac{b}{a}+\frac{a}{b}\right)^2 E\left(\frac{t_p}{b}\right)^2$	
(b) Pure shear:	$\tau_e = 3,62\left(1,335+\left(\frac{u}{v}\right)^2\right)E\left(\frac{t_p}{u}\right)^2$ NOTE *u* is to be the minimum dimension	
Note The critical buckling stresses, in N/mm^2, are to be derived from the elastic buckling stresses as follows:		

$\sigma_c = \sigma_e$ when $\sigma_e < \frac{\sigma_a}{2}$ $= \sigma_a \left(1 - \frac{\sigma_a}{4\sigma_e}\right)$ when $\sigma_e \geq \frac{\sigma_a}{2}$ σ_c is defined in *Pt 7, Ch 7, 4.2 Symbols 4.2.1* σ_a is defined in *Pt 7, Ch 7, 4.2 Symbols 4.2.1*	$\tau_c = \tau_e$ when $\tau_e < \frac{\tau_a}{2}$ $= \tau_a \left(1 - \frac{\tau_a}{4\tau_e}\right)$ when $\tau_e \geq \frac{\tau_a}{2}$ τ_c is defined in *Pt 7, Ch 7, 4.2 Symbols 4.2.1* τ_a is defined in *Pt 7, Ch 7, 4.2 Symbols 4.2.1*
Symbols and definitions	
A_R = panel aspect ratio, *see Pt 7, Ch 7, 4.2 Symbols 4.2.1* σ_e = elastic compressive buckling stress, in N/mm^2 τ_e = elastic shear buckling stress, in N/mm^2 *a* and *b* are the panel dimensions in mm, *see* figures above t_p = thickness of plating, in mm φ = stress distribution factor for linearly varying compressive stress across plate width = 0,47 μ^2 - 1,4 μ + 1,93 for $\mu \geq 0$ = 1 for constant stress $\mu = \frac{\sigma_{d1}}{\sigma_{d2}}$ where σ_{d1} and σ_{d2} are the smaller and larger average compressive stresses respectively	*E* = Young's Modulus of elasticity of material, in N/mm^2 *C* = stiffener influence factor for panels with stiffeners perpendicular to compressive stress = 1,3 when plating stiffened by floors or deep girders = 1,21 when stiffeners are built up profiles or rolled angles = 1,10 when stiffeners are bulb flats = 1,05 when stiffeners are flat bars σ_d and τ_d are the design compressive and design shear stresses in the direction illustrated in the figures. With linearly varying stress across the plate panel, σ_d is to be taken as σ_{d2}

Table 7.4.2 Plate panel buckling requirements

	Stress field	Buckling Interaction formula	
(a)	uni-axial compressive loads	$\frac{\sigma_d}{\sigma_c} \leq \frac{1}{\lambda_s}$	
(b)	shear loads	$\frac{\tau_d}{\tau_c} \leq \frac{1}{\lambda_t}$	

(c)	bi-axial compressive loads	for $A_R = 1,0$ $\frac{\sigma_{dx}}{\sigma_{cx}} + \frac{\sigma_{dy}}{\sigma_{cy}} \le 1,0$ for other aspect ratios, i.e. AR ≠ 1,0 $\frac{\sigma_{dx}}{\sigma_{cx}} + \frac{\sigma_{dy}}{\sigma_{cy}} \le G$ when G is taken from *Figure 7.4.2 Secondary stiffening perpendicular to direction of compression*	
(d)	uni-axial compressive loads plus shear load	for $A_R > 1$ $\left(\frac{\sigma_d}{\sigma_c}\right) + \left(\frac{\tau_d}{\tau_c}\right)^2 \le 1$ for $A_R \le 1$ $\left(\frac{1 + 0,6A_R}{1,6}\right)\left(\frac{\sigma_d}{\sigma_c}\right) + \left(\frac{\tau_d}{\tau_c}\right)^2 \le 1$	

(e)	bi-axial compressive loads plus shear loads	$\frac{0,625\left(1+\frac{0,6}{A_{R}}\right)\left(\frac{\sigma_{dy}}{\sigma_{cy}}\right)}{1-0,625\left(\frac{\sigma_{dx}}{\sigma_{cx}}\right)}+\frac{\left(\frac{\tau_{d}}{\tau_{c}}\right)^{2}}{1-\left(\frac{\sigma_{dx}}{\sigma_{cx}}\right)} \le 1$	
Symbols			

σ_{d} = design compressive stress, *see Pt 7, Ch 7, 4.1 General 4.1.3*

σ_{c} = critical compressive buckling stress, in N/mm^{2}, for uniaxial compressive load acting independently, *see Pt 7, Ch 7, 4.3 Plate panel buckling requirements 4.3.5*

σ_{dx} = design compressive stress in x direction

σ_{dy} = design compressive stress in the y direction

σ_{cx} = critical compressive buckling stress in x direction, *see Pt 7, Ch 7, 4.3 Plate panel buckling requirements 4.3.5*

σ_{cy} = critical compressive buckling stress in y direction, *see Pt 7, Ch 7, 4.3 Plate panel buckling requirements 4.3.5*

λ_{s} = buckling factor of safety for compressive stresses, *see Pt 7, Ch 7, 4.3 Plate panel buckling requirements 4.3.4*

λ_{t} = buckling factor of safety for shear stresses, *see Pt 7, Ch 7, 4.3 Plate panel buckling requirements 4.3.4*

τ_{d} = design shear stress, in N/mm^{2}

τ_{c} = critical shear buckling stress, in N/mm^{2}, acting independently, *see Pt 7, Ch 7, 4.3 Plate panel buckling requirements 4.3.5*

A_{R} = *see Pt 7, Ch 7, 4.2 Symbols 4.2.1*

4.4.3 For welded plate panels the critical compressive buckling stress is to be reduced to account for the presence of residual welding stresses. The critical buckling stress is to be taken as the minimum of:

$\sigma_{cr} = \sigma_{e} - \sigma_{r}$

σ_{c} = derived using *Pt 7, Ch 7, 4.4 Derivation of the buckling stress for plate panels 4.4.1*

where

σ_{r} = reduction in compressive buckling stress due to residual welding stresses

$$= \frac{2\,\beta_{RS}\,\sigma_{a}}{b/t_{p}}$$

β_{RS} = residual stress coefficient dependent on type of weld (average value of β_{RS} to be taken as 3)

b, t_{p} and σ_{a} = are defined in *Pt 7, Ch 7, 4.2 Symbols 4.2.1*

4.4.4 In general the effect of lateral loading on plate panels (for example hydrostatic pressure on bottom shell plating) may be neglected and the critical buckling stresses calculated considering the in-plane stresses only.

4.4.5 Unless indicated otherwise, the effect of initial deflection on the buckling strength of plate panels may be ignored.

4.5 Additional requirements for plate panels which buckle elastically

4.5.1 Elastic buckling of plate panels between stiffeners occurs when both the following conditions are satisfied:

(a) The design compressive stress, σ_d, is greater than the elastic buckling stress of the plating, σ_e,

$\sigma_d > \sigma_e$

(b) The elastic buckling stress is less than half the yield stress

$$\sigma_e \leq \frac{\sigma_a}{2}$$

4.5.2 Elastic buckling of local plating between stiffeners, including girders or floors etc, may be allowed if all of the following conditions are satisfied:

(a) The critical buckling stress of the stiffeners in all buckling modes is greater than the axial stress in the stiffeners after redistribution of the load from the elastically buckled plating into the stiffeners, hence

$$\frac{\sigma_{de}}{\sigma_{c(i)}} \leq \frac{1}{\lambda_s}$$

(b) Maximum predicted loadings are used in the calculations.

(c) Functional requirements will allow a degree of plating deformation.

where

σ_{de} = is the stiffener axial stress given in *Pt 7, Ch 7, 4.5 Additional requirements for plate panels which buckle elastically 4.5.5*

$\sigma_{c(i)}$ = is given by *Table 7.4.3 Buckling stress of secondary stiffeners*

where

i = a, t, w or f depending on the mode of buckling.

λ_σ = is the buckling factor of safety

= 1,25.

Table 7.4.3 Buckling stress of secondary stiffeners

Mode	Elastic buckling stress, N/mm^2	Critical buckling stress, N/mm^2 *see* Note
(a) Overall buckling (perpendicular to plane of plating without rotation of cross-section)	$\sigma_{e(a)} = C_f 0,001E \frac{I_a}{A_{te} l_e^2}$	$\sigma_{c(a)}$
(b) Torsional buckling	$\sigma_{e(t)} = \frac{0,001EI_w}{I_p l_e^2}\left(m^2 + \frac{K}{m^2}\right) + 0,385E\frac{I_t}{I_p}$	$\sigma_{c(t)}$
(c) Web buckling (excluding flat bar stiffeners)	$\sigma_{e(w)} = 3,8E\left(\frac{t_w}{d_w}\right)^2$	$\sigma_{c(w)}$
(d) Flange buckling	$\sigma_{e(f)} = 0,39E\left(\frac{t_f}{b_f}\right)^2$	$\sigma_{c(f)}$

The critical buckling stresses are to be derived from the elastic buckling stresses as follows:

σ_c = σ_e when $\sigma_e < \dfrac{\sigma_a}{2}$

= $\sigma_a \left(1 - \dfrac{\sigma_a}{4\sigma_e}\right)$ when $\sigma_e \geq \dfrac{\sigma_a}{2}$

Symbols

d_w = web depth, in mm, (excluding flange thickness for rolled sections), *see Figure 7.4.4 Dimensions of longitudinals*

t_w = web thickness, in mm

b_f = flange width, in mm (including web thickness)

t_f = flange thickness, in mm. For bulb plates, the mean thickness of the bulb may be used, *see Figure 7.4.4 Dimensions of longitudinals*

l_e = effective span length of secondary stiffener in metres

C_f = end constraint factor

= 1 where both ends are pinned

= 2 where one end pinned and the other end fixed

= 4 where both ends are fixed

E = Young's Modulus of elasticity of the material, in N/mm^2

I_a = moment of inertia, in cm^4, of longitudinal, including attached plating of effective width b_{eb}, *see* Note

t_p and σ_a are given in *Pt 7, Ch 7, 4.2 Symbols 4.2.1*

A_{te} and b_{eb} are given in *Pt 7, Ch 7, 4.2 Symbols 4.2.1*

I_t = St Venant's moment of inertia, in cm^4, of longitudinal (without attached plating)

= $\dfrac{d_w t_w^3}{3} 10^{-4}$ for flat bars

= $\dfrac{1}{3}\left[d_w t_w^3 + b_f t_f^3 \left(1 - \dfrac{0,63 t_f}{b_f}\right)\right] 10^{-4}$ for built up profiles, rolled angles and bulb plates

I_p = polar moment of inertia, in cm^4, of profile about connection of stiffener to plating

= $\dfrac{d_w^3 t_w}{3} 10^{-4}$ for flat bars

= $\left(\dfrac{d_w^3 t_w}{3} + d_w^2 b_f t_f\right) 10^{-4}$ for built up profiles, rolled angles and bulb plates

I_w = sectorial moment of inertia, in cm^6, of profile and connection of stiffener to plating

$= \frac{d_w{}^3 t_w{}^3}{36} 10^{-6}$ for flat bars

$= \frac{t_f b_f{}^3 d_w{}^2}{12} 10^{-6}$ for `Tee' profiles

$= \frac{b_f{}^3 d_w{}^2}{12(b_f + d_w)^2}\left(t_f\left(b_f{}^2 + 2b_f d_w + 4d_w{}^2\right) + 3t_w b_f d_w\right)10^{-6}$ for `*L*' profiles, rolled angles and bulb plates

C = spring stiffness exerted by supporting plate panel

$$= \frac{k_p E t_p{}^3}{3b\left(1 + \frac{1,33 k_p d_w t_p{}^3}{b t_w{}^3}\right)}$$

k_p = 1-η_p, and is not to be taken as less than zero. For built up profiles, rolled angles and bulb plates, k_p need not be taken less than 0,1

$\eta_p = \frac{\sigma_a}{\sigma_{ep}}$

σ_{ep} = elastic critical buckling stress, in N/mm^2, of the supporting plate derived from *Table 7.4.1 Buckling stress of plate panels*

m is determined as follows: e.g. *m* = 2 for *K* = 25

K	0 to 4	4 to 36	36 to 144	144 to 400	400 to 900	900 to 1764	$(m - 1)^2 m^2$ to $m^2(m + 1)^2$
m	1	2	3	4	5	6	*m*

$K = \frac{1,03 C S^4}{E I_w} 10^4$

σ_d is the design stress, in N/mm^2

all other symbols are as defined in *Pt 7, Ch 7, 4.2 Symbols 4.2.1*.

Note For stiffeners attached to plating which buckles elastically, *see Pt 7, Ch 7, 4.5 Additional requirements for plate panels which buckle elastically*, the effective width of plating is to be taken as b_{eu}.

Table 7.4.4 Buckling factor of safety

Structural item	Buckling factor of safety (2) Compressive stresses, λ_σ	Buckling factor of safety (3) Shear stresses, λ_t
Bottom shell plating	1,0	–
Inner bottom plating	1,0	–

Deck plating	1,0	–
Side shell plating	1,0	1,1
Longitudinal bulkhead plating	1,0	1,1
Double bottom girders	1,0	1,1
Longitudinal girders	1,0	1,1
Superstructures/deckhouses (partially longitudinally effective)	1,0	–
Longitudinal secondary stiffeners	1,1(1)	–
Girder and floor web plating subject to local loads	1,1	1,2

Note 1. The buckling factor of safety for stiffeners attached to plating which is allowed to buckle in the elastic mode due to the applied loads is to be taken as 1,25, see also *Pt 7, Ch 7, 4.5 Additional requirements for plate panels which buckle elastically*.

Note 2. Buckling factor of safety to be applied to the compressive stress due to global longitudinal stresses.

Note 3. Buckling factor of safety to be applied to the shear stress.

4.5.3 The effective breadth of attached plating for stiffeners, girder or beams that is to be used for the determination of the critical buckling stress of the stiffeners attached to plating which buckles elastically is to be taken as follows:

$$b_{eu} = \frac{b\,\sigma_u}{\sigma_a} \text{ mm}$$

where

σ_u = ultimate buckling strength of plating as given in *Pt 7, Ch 7, 4.5 Additional requirements for plate panels which buckle elastically 4.5.4*

b_{eu} = effective panel breadth perpendicular to direction of compressive stress being considered

b = is given in *Pt 7, Ch 7, 4.2 Symbols 4.2.1*.

4.5.4 The ultimate buckling strength of plating, σ_u, which buckles elastically, may be determined as follows:

(a) shortest edge loaded, i.e. $A_R \geq 1$:

(b) $$\sigma_u = \sigma_a\left(\frac{1,9}{W} - \frac{0,8}{W^2}\right)\text{N/mm}^2$$

(c) longest edge loaded, i.e. $A_R < 1$:

(d) $$\sigma_u = \frac{1,77\,\sigma_a A_R^{0,78}}{W}\text{ N/mm}^2$$

where

$$W = \frac{s}{t_p}\sqrt{\frac{\sigma_a}{E}}$$

A_R and s are defined in *Pt 7, Ch 7, 4.2 Symbols 4.2.1*.

t_p, E and σ_a are defined in *Pt 7, Ch 7, 4.2 Symbols 4.2.1*.

4.5.5 The axial stress in stiffeners attached to plating which is likely to buckle elastically is to be derived as follows:

$$\sigma_{de} = \sigma_d\,\frac{A_t}{A_{tb}}$$

where

σ_d = is the axial stress in the stiffener when the plating can be considered fully effective

where

A_t = $A_s + \dfrac{bt}{100}$ cm^2

A_{tb} = $A_s + \dfrac{b_{eu}t}{100}$ cm^2

where

b and b_{eu} = are given in *Pt 7, Ch 7, 4.5 Additional requirements for plate panels which buckle elastically 4.5.3*

t = is the plating thickness, in mm

A_s = is the stiffener area in cm^2.

4.6 Shear buckling of stiffened panels

4.6.1 The shear buckling capability of longitudinally stiffened panels between primary members is to satisfy the following condition:

$$\frac{\tau_d}{\tau_c} \leq \frac{1}{\lambda_t}$$

where

τ_c = is derived from *Pt 7, Ch 7, 4.6 Shear buckling of stiffened panels 4.6.3*

τ_d = is the design shear stress

λ_τ = is given in *Table 7.4.3 Buckling stress of secondary stiffeners*.

4.6.2 The elastic shear buckling stress of longitudinally stiffened panels between primary members may be taken as:

τ_e = $K_s E \left(\frac{t}{s}\right)^2$ for $A_R \geq 1$

where

K_s = $4{,}5\left(\left(\frac{s}{1000l}\right)^2 + \frac{1}{N^2} + \left(\frac{N^2-1}{N^2}\right)\left(\frac{\omega}{1+\omega}\right)^r\right)$

N = number of subpanels

= $\dfrac{1000S_p}{s}$

ω = $\dfrac{10I_{se}}{lt^3}$

I_{se} = moment of inertia of a section, in cm^4, consisting of the longitudinal stiffener and a plate flange of effective width s/2

r = $1 - 0{,}75\left(\frac{s}{1000l}\right)$

s, l , E and S_p are as defined in *Pt 7, Ch 7, 4.2 Symbols 4.2.1*, *see also Figure 7.4.1 Shear buckling of stiffened panels*.

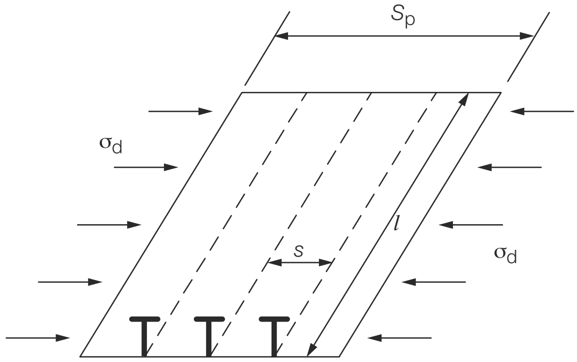


Figure 7.4.1 Shear buckling of stiffened panels

4.6.3 The critical shear buckling stress, τ_c, may be determined from t_e, *see* Note in *Table 7.4.1 Buckling stress of plate panels*.

4.7 Secondary stiffening in direction of compression

4.7.1 The buckling performance of stiffeners will be considered satisfactory if the following conditions are satisfied:

$$\frac{\sigma_d}{\sigma_{c(a)}} \leq \frac{1}{\lambda_\sigma} \qquad \frac{\sigma_d}{\sigma_{c(t)}} \leq \frac{1}{\lambda_\sigma}$$

$$\frac{\sigma_d}{\sigma_{c(w)}} \leq \frac{1}{\lambda_\sigma} \qquad \frac{\sigma_d}{\sigma_{c(f)}} \leq \frac{1}{\lambda_\sigma}$$

where

$\sigma_{c(a)}$, $\sigma_{c(t)}$, $\sigma_{c(w)}$ and $\sigma_{c(f)}$ are the critical buckling stresses of the stiffener for each mode of failure, *see Pt 7, Ch 7, 4.7 Secondary stiffening in direction of compression 4.7.2*

σ_d is the design compressive stress, *see also Pt 7, Ch 7, 4.5 Additional requirements for plate panels which buckle elastically* and *Pt 7, Ch 7, 4.1 General 4.1.3*

λ_σ is the buckling factor of safety given in *Table 7.4.4 Buckling factor of safety*. The value of λ_σ to be chosen depends on the buckling assessment of the attached plating, *see Table 7.4.4 Buckling factor of safety*.

4.7.2 The critical buckling stresses for the overall, torsional, web and flange buckling modes of longitudinals and secondary stiffening members under axial compressive loads are to be determined in accordance with *Table 7.4.3 Buckling stress of secondary stiffeners*.

4.7.3 To prevent torsional buckling of secondary stiffeners from occurring before buckling of the plating, the critical torsional buckling stress, $\sigma_{c(t)}$, is to be greater than the critical buckling stress of the attached plating as detailed in *Pt 7, Ch 7, 4.4 Derivation of the buckling stress for plate panels 4.4.1*

4.7.4 The critical buckling stresses of the stiffener web, $\sigma_{c(w)}$, and flange, $\sigma_{c(f)}$, are to be greater than the critical torsional buckling stress, hence:

(a) $\sigma_{c(w)} > \sigma_{c(t)}$

(b) $\sigma_{c(f)} > \sigma_{c(t)}$

4.7.5 To ensure that overall buckling of the stiffened panel cannot occur before local buckling of the secondary stiffener, the critical overall buckling stress $\sigma_{c(a)}$, is to be greater than the critical torsional buckling stress, hence

$\sigma_{c(a)} > \sigma_{c(t)}$

4.8 Secondary stiffening perpendicular to direction of compression

4.8.1 Where a stiffened panel of plating is subjected to a compressive load perpendicular to the direction of the stiffeners, *see Figure 7.4.2 Secondary stiffening perpendicular to direction of compression*, e.g. a transversely stiffened panel subject to longitudinal compressive load, the requirements of this Section are to be applied.

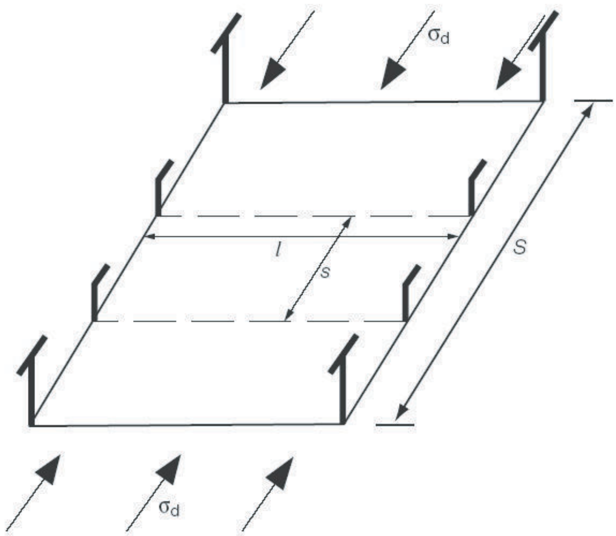


Figure 7.4.2 Secondary stiffening perpendicular to direction of compression

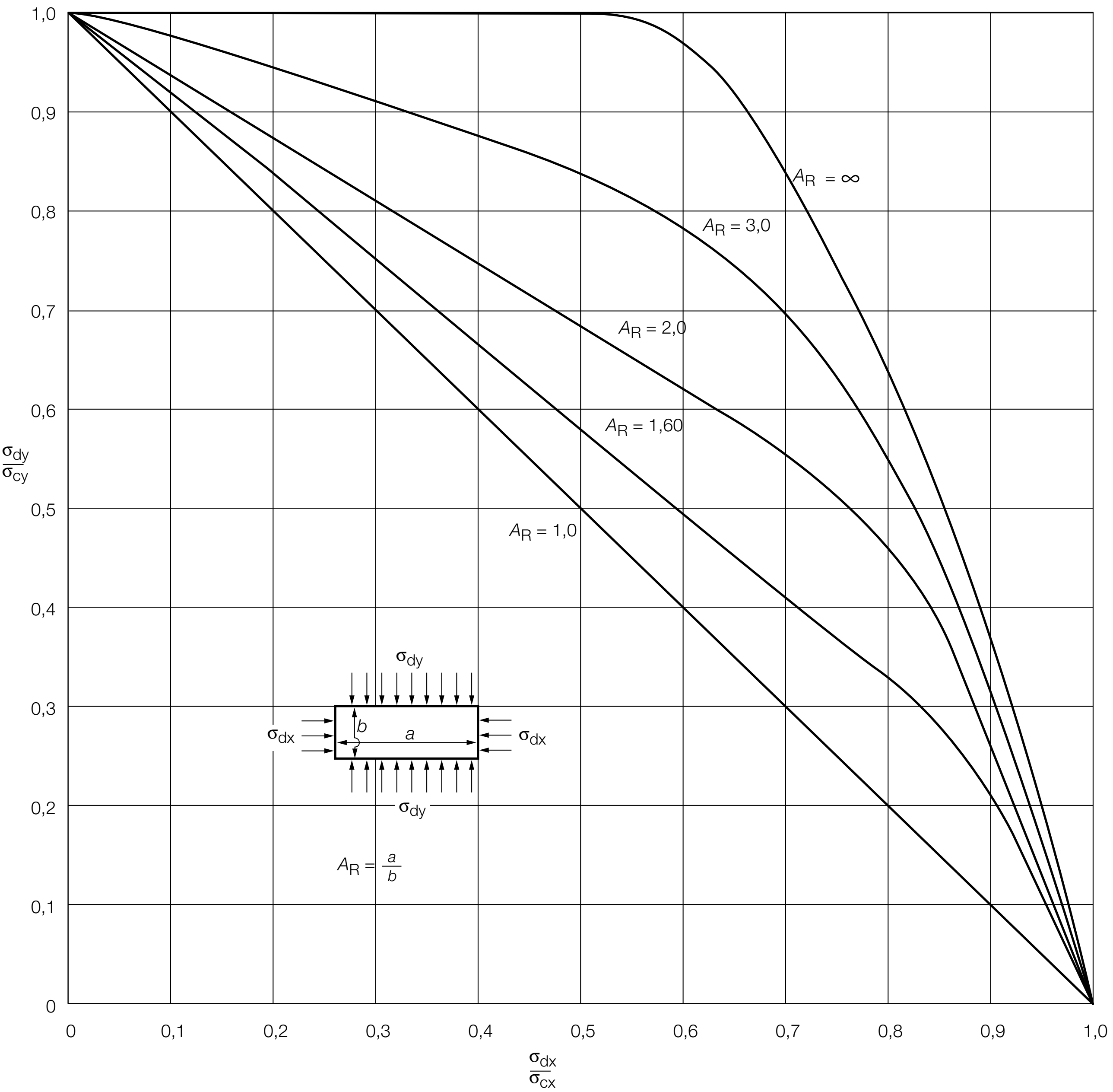


Figure 7.4.3 Interaction limiting stress curves of G for plate panels subject to bi-axial compression, ***see Pt 6, Ch 7, 4.4 Derivation of the buckling stress for plate panels 4.4.2***

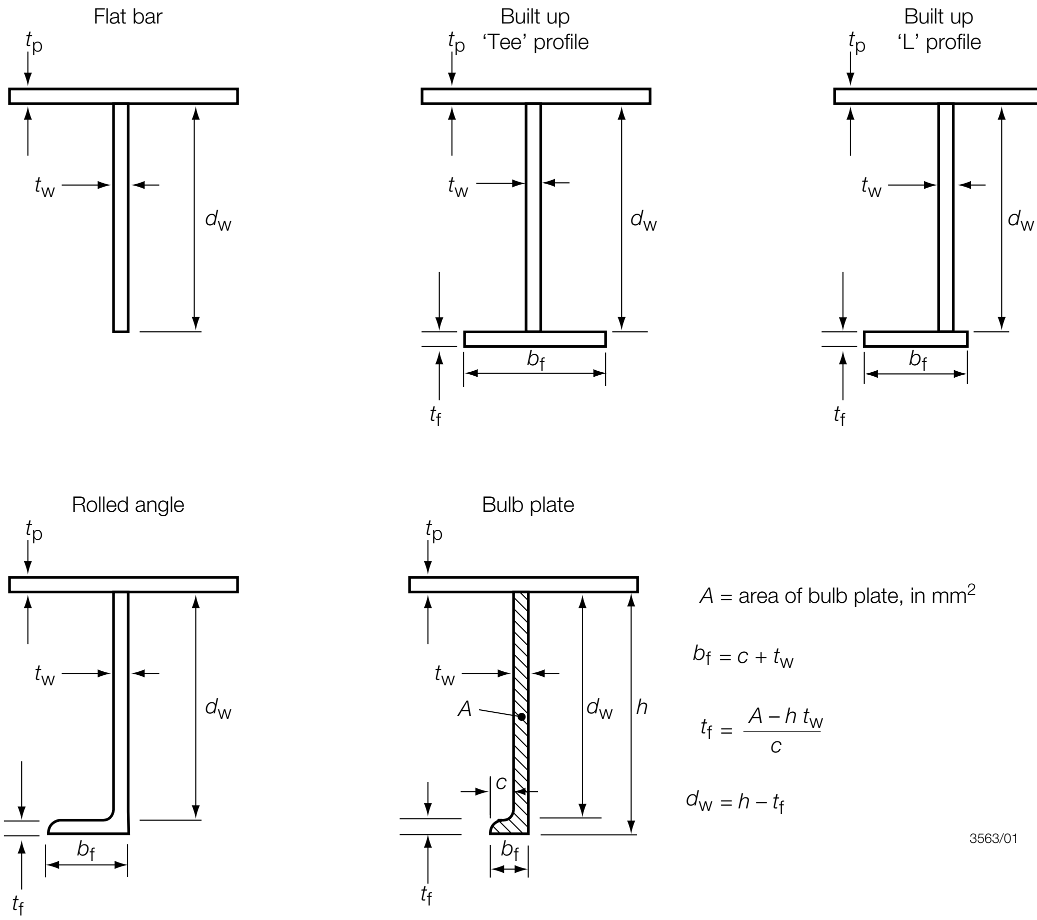


Figure 7.4.4 Dimensions of longitudinals

4.8.2 The minimum area moment of inertia of each stiffener including attached plating of width, s, to ensure that overall panel buckling does not precede plate buckling is to be taken as:

$$= \quad I_s = \frac{Ds\left(4N_L^2 - 1\right)\left(\left(N_L^2 - 1\right)^2 - 2\left(N_L^2 + 1\right)\kappa + \kappa^2\right)}{2\left(5N_L^2 + 1 - \kappa\right) \quad 4E} \text{ mm}^4$$

where

$D = \dfrac{Et_p^3}{12\left(1 - u^2\right)}$

$\kappa = A_R^{\,2}\Pi^2$

A_R = plate panel aspect ratio

$= \dfrac{s}{1000l}$

$\Pi = \dfrac{S}{l}$

N_L = number of plate panels

$N_L - 1$ = number of stiffeners

where

υ = 0,3

s, *l* and *S* are defined in *Pt 7, Ch 7, 4.2 Symbols 4.2.1* and shown in *Figure 7.4.2 Secondary stiffening perpendicular to direction of compression*

t_p, *E* are defined in *Pt 7, Ch 7, 4.2 Symbols 4.2.1*.

4.9 Buckling of primary members

4.9.1 Where primary girders are subject to axial compressive loading, the buckling requirements for lateral, torsional, web and flange buckling modes detailed in *Pt 7, Ch 7, 4.7 Secondary stiffening in direction of compression* are to be satisfied.

4.9.2 To prevent global buckling from occurring before local panel buckling, transverse primary girders supporting axially loaded longitudinal stiffeners are to have a sectional moment of inertia, including attached plating, of not less than the following:

$$I_g = \frac{0,35 S_p^4 I_s}{l^3 s} \times 10^3 \text{ cm}^4$$

S_p and *s* are as defined in *Pt 7, Ch 7, 4.2 Symbols 4.2.1*, *see also Figure 7.4.1 Shear buckling of stiffened panels*

I_g = sectional moment of inertia including attached plating

I_s = moment of inertia of secondary stiffeners, in cm^4, required to satisfy the overall elastic column buckling mode requirement specified in *Table 7.4.3 Buckling stress of secondary stiffeners*

$$= \frac{\sigma_{ep} A_{te} l_e^2}{0,001E}$$

where

σ_{ep} = 1,2σ_d N/mm^2 for $\sigma_{e(a)} < \frac{\sigma_a}{2}$

$$= \frac{\sigma_a^2}{4(\sigma_a - 1,2\sigma_d)} \text{ for } \sigma_{e(a)} \geq \frac{\sigma_a}{2}$$

σ_d is design stress, in N/mm^2

σ_a and A_{te} are as defined in *Pt 7, Ch 7, 4.2 Symbols 4.2.1*.

$\sigma_{e(a)}$ is the elastic column buckling stress, *see Pt 7, Ch 7, 4.7 Secondary stiffening in direction of compression 4.7.2*

E is defined in *Pt 7, Ch 7, 4.2 Symbols 4.2.1*

l_e is defined in *Table 7.4.3 Buckling stress of secondary stiffeners*

4.10 Shear buckling of girder webs

4.10.1 Local panels in girder webs subject to in-plane shear loads are to satisfy the shear buckling requirements in *Table 7.4.2 Plate panel buckling requirements*, item (b).

4.10.2 The critical shear buckling stress, τ_c, is to be determined using the following formula for τ_e and the Note in *Table 7.4.1 Buckling stress of plate panels*.

$$\tau_e = 3,62\left(1,335 + \left(\frac{d_w}{1000 l_p}\right)^2\right) E \left(\frac{t_p}{d_w}\right)^2 \text{ N/mm}^2$$

where

d_w = web height, in mm

l_p = unsupported length of web, in metres

t_p and E are defined in *Pt 7, Ch 7, 4.2 Symbols 4.2.1*.

4.11 Pillars and pillar bulkheads

4.11.1 Pillars and pillar bulkheads are to comply with the requirements of *Pt 7, Ch 3, 10 Pillars and pillar bulkheads*.

Section 5 Vibration control

5.1 General

5.1.1 Natural frequencies are to be investigated for local unstiffened and stiffened panels expected to be exposed to excessive structural vibrations being induced from machinery, propulsion unit or other potential excitation sources.

5.1.2 Where the structural configurations are such that basic structural elements may be modelled individually the natural frequencies may be derived in accordance with *Pt 7, Ch 7, 5.3 Natural frequency of plate*, *Pt 7, Ch 7, 5.4 Natural frequency of plate stiffener* and *Pt 7, Ch 7, 5.5 Effect of submergence*, as appropriate. Under other circumstances finite element analysis is to be employed to evaluate the vibration characteristics of the structure considered.

5.2 Frequency band

5.2.1 The natural frequency of panels is generally not to lie within a band of ±20 per cent of a significant excitation frequency.

5.3 Natural frequency of plate

5.3.1 The natural frequency of a clamped plate in air is given by the following:

$$f_{air} = 5,544\frac{t_p}{ab}\sqrt{\left(\frac{a}{b}\right)^2 + \left(\frac{b}{a}\right)^2 + 0,6045}\ \text{Hz}$$

where

a = panel length, in metres

b = panel breadth, in metres

t_p = panel thickness, in mm

5.4 Natural frequency of plate stiffener

5.4.1 The natural frequency of a plate stiffener in air is given by the following:

$$f_{\text{air, i}} = \frac{K_i}{2\,\pi\,L_b^2}\sqrt{\frac{EI}{m\left(1 + \frac{\pi^2 EI}{L_b^2 GA}\right)}}\ \text{Hz}$$

where

EI = flexural rigidity of plate stiffener combination, in Nm^2

GA = shear rigidity of plate stiffener combination, in N

L_b = beam length, in metres

m = mass per unit length of the stiffener and associated plating, in kg/m

K_i = constant where i refers to the mode of vibration as given in *Table 7.5.1 Vibration mode constant* K_i

Table 7.5.1 Vibration mode constant K_i

Mode	1	2	3	4	5
K_i	22,40	61,70	121,0	200,0	299,0

5.5 Effect of submergence

5.5.1 To obtain the frequency, f_{water}, of a plate with one side exposed to air and the other side exposed to a liquid, the frequency calculated in air, f_{air}, may be modified by the following formula:

$$f_{water} = \psi f_{air}$$

where

$$= \quad \psi = \sqrt{\frac{\kappa_p}{\kappa_p + \frac{\rho_l}{\rho_p}}}$$

ρ_l = density of the liquid, in kg/m^3

ρ_p = density of the plate, in kg/m^3

κ_p = $\dfrac{\pi t_p}{1000ab}\sqrt{a^2 + b^2}$

where a, b and t_p are as defined in *Pt 7, Ch 7, 5.3 Natural frequency of plate 5.3.1*.

Contents

Section 1
Application

1.1 General

1.1.1 The Rules are applicable to mono and multi-hull craft of normal form, proportions and speed. Although the Rules are, in general, for fibre reinforced composite craft of laminated construction, other materials for use in hull construction will be specially considered on the basis of the Rules.

1.1.2 The Rules provide for craft of both single and sandwich skin construction.

1.2 Interpretation

1.2.1 The interpretation of the Rules is the sole responsibility and at the sole discretion of Lloyd's Register (hereinafter referred to as 'LR'). Where there is any doubt regarding the interpretation of the Rules it is the Builder's and/or designer's responsibility to obtain clarification from LR prior to submission of plans and data for appraisal.

1.2.2 Where applicable, the Rules take into account unified requirements and interpretations established by the International Association of Classification Societies (IACS).

1.2.3 Attention is drawn to the fact that Codes of Practice issued by IMO or other applicable National Authorities may contain requirements which are outside classification as defined in the Rules.

1.3 Equivalents

1.3.1 Alternative scantlings and arrangements may be accepted as equivalent to the Rule requirements. Details of such proposals are to be submitted for consideration in accordance with *Pt 3, Ch 1, 3 Equivalents*.

1.4 Symbols and definitions

1.4.1 The symbols and definitions for use throughout this Part are as defined within the appropriate Chapters and Sections.

Section 2
General requirements

2.1 General

2.1.1 Specific limitations regarding the application of the Rules are indicated in the various Chapters for differing types of craft.

2.2 Aesthetics

2.2.1 LR is not concerned with the general arrangement, layout and appearance of the craft; the responsibility for such matters remains with the Builders and/or designers to ensure that the agreed specification is complied with. LR is, however, concerned with the quality of workmanship, and in this respect the acceptance criteria as required by the Rules are to be complied with.

2.3 Constructional configuration

2.3.1 The Rules provide for the basic structural configurations for both single and multi-deck mono and multi-hull craft with single or double bottom arrangements. The structural configuration may also include a single or multiple arrangement of cargo hatch openings and side tanks.

2.3.2 The Rules provide for longitudinal and transverse framing systems.

2.3.3 Novel or other types of framing systems will be considered on the basis of the Rules.

2.4 Plans to be submitted

2.4.1 Plans covering the following items are to be submitted:

- Midship sections showing longitudinal and transverse material.
- Profile and decks.
- Deck hatches.
- Bridging structure.
- Shell expansion.
- Laminate schedule.
- Oiltight and watertight bulkheads.
- Propeller brackets.
- Integral tanks.
- Double bottom construction.
- Pillars and girders.
- Aft end construction.
- Engine room construction.
- Engine and thrust seatings.
- Fore end construction.
- Doors, hatches, windows and portlights.
- Deckhouses and superstructures.
- Sternframe.
- Rudder, stock and tiller.
- Anchor and mooring equipment.
- Any special arrangements (e.g. anchor deployment systems, submarine anchor pockets).
- Loading manuals, preliminary and final (where applicable).
- Ice strengthening.
- Welding (where applicable).
- Hull penetration plans.
- Support structure for masts, derrick posts or cranes.
- Bilge keels showing connections and detail design.
- Chain-plates.

2.4.2 The following supporting documents are to be submitted:

- General arrangement.
- Capacity plan.
- Modes of operation for which the craft is designed (speeds corresponding to displacement and non-displacement mode as applicable).
- Lines plan or equivalent.
- Dry-docking plan.
- Towing and mooring arrangements.
- Sail/rigging plan, indicating loadings (as applicable to sailing craft).

2.4.3 The following supporting calculations are to be submitted, *see also Pt 8, Ch 1, 2.7 Direct calculations*:

- Equipment Number.
- Hull girder still water and dynamic wave bending moment and shear force as applicable.

- Midship section stiffness.
- Structural items in the aft end, midship and fore end regions of the craft.
- Preliminary freeboard calculation.

2.5 Materials data sheet

2.5.1 Details of all the approved and accepted plastics materials, as required by the Rules, are to be submitted on LR's Reinforced Plastic Structures Materials Data Sheet (Form 2075) with the initial submission of plans. Reference is to be made to *Pt 8, Ch 2, 2 Materials*. The types and quantities of curing systems identified on the Materials Data Sheet are to be those recommended by the resin manufacturer for the approved resin systems.

2.5.2 When specifying materials, the exact manufacturer's type designation, identification and reference numbers are to be quoted.

2.5.3 All sandwich core materials are to be of a type acceptable to LR and are to be clearly identified together with any core bonding adhesive to be used.

2.5.4 Fibre contents by weight for each type of reinforcement are to be reported.

2.5.5 All relevant post curing data is to be documented on the Materials Data Sheet.

2.6 Novel features

2.6.1 Where the proposed construction of any part of the hull or machinery is of novel design, or involves the use of unusual material, or where experience, in the opinion of LR, has not sufficiently justified the principle or mode of application involved, special tests or examinations before and during service may be required. In such cases a suitable notation may be entered in the appropriate *Register Book*.

2.7 Direct calculations

2.7.1 Direct calculations may be specifically required by the Rules and may be required for craft having novel design features or in support of alternative arrangements and scantlings. LR may, when requested, undertake calculations on behalf of the designers and make recommendations in regard to suitability of any required model tests.

2.7.2 Where direct calculations are proposed then the requirements of *Pt 3, Ch 1, 2 Direct calculations* are, in general, to be complied with.

2.8 Exceptions

2.8.1 Craft of unusual form, proportions or speed, intended for the carriage of special cargoes, not covered specifically by the Rules, will receive individual consideration based on the general requirements of the Rules.

2.9 Advisory services

2.9.1 The Rules do not cover certain technical characteristics, such as stability, except as mentioned in *Pt 1, Ch 2, 1.1 General 1.1.11* and *Pt 1, Ch 2, 1.1 General 1.1.13* , trim, vibration, docking arrangements, etc. The Committee cannot assume responsibility for these matters but is willing to advise upon them on request.

Section

Section 1
General requirements

1.1 General

1.1.1 The Rules are applicable to craft generally constructed of fibre reinforced plastic in accordance with *Pt 8, Ch 2, 2.1 General 2.1.1*.

1.1.2 All construction is to be carried out using materials and techniques approved or accepted by Lloyd's Register (hereinafter referred to as 'LR'). Where non-approved or non-accepted materials or production techniques are proposed, it is the responsibility of the Builder and manufacturer to obtain the necessary approval or acceptance and demonstrate their equivalence on the basis of the Rules.

1.1.3 It is the Builder's responsibility to ensure that all materials are used in accordance with the manufacturer's instructions.

1.2 Definitions

1.2.1 Definitions for use throughout this Chapter are as indicated in the appropriate Sections.

1.3 Symbols

1.3.1 Symbols for use throughout this Chapter are as indicated in the appropriate Sections.

1.4 Builder's facilities

1.4.1 *Pt 8, Ch 2, 1.4 Builder's facilities* and *Pt 8, Ch 2, 1.5 Works inspection* are applicable to the facilities and works for the craft under survey.

1.4.2 The buildings used for production and storage are to be of suitable construction and equipped to provide the required environment, and are to comply with any local or National Authority requirements.

1.4.3 Workshops and equipment are to be in accordance with good manufacturing practice and are to be to the satisfaction of the Surveyor.

1.4.4 The Surveyor is to be allowed unrestricted access during working hours to such parts of the Builder's establishment as may be necessary to ensure that the requirements of the Rules are being complied with.

1.5 Works inspection

1.5.1 Prior to the commencement of production the facilities are to be inspected to the satisfaction of the attending Surveyor. This is to include evidence that the mandatory minimum quality control requirements as outlined in *Pt 8, Ch 2, 1.6 Quality control* and *Ch 14, 5 Control of material quality for composite construction*of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials), are fulfilled.

1.5.2 The Surveyor is to be satisfied that the Builder has the organisation and capability to mould craft to the standards required by the Rules.

1.5.3 The Builder is to rectify any deficiencies to the Surveyor's satisfaction prior to the commencement of production.

1.5.4 The validity of the acceptance of the Builder's works for moulding craft under LR survey is subject to an annual QC audit and monitoring by the attending Surveyor. Where there is a break in the continuity of moulding under LR survey, the facilities will in general, be subject to an additional inspection prior to any recommencement of any moulding carried out under LR survey.

1.5.5 For acceptance the survey is to include procedures covering the Builder's management, organisation and quality systems.

1.6 Quality control

1.6.1 The Builder's mandatory quality systems for composite construction, will be subject to inspection and audit, and are to be in accordance with the requirements of one of the following:

(a) Quality Assurance System in accordance with an International or National Standard (i.e. ISO 9000 and BS ENISO 9001) with assessment and certification carried out by a nationally accredited body and must reflect the minimum quality control requirements under (c) being complied with.
(b) LR's locally accepted Quality Control System - The Builder is implementing a documented Quality Control System which controls the activities as indicated below, *see also Ch 14, 5 Control of material quality for composite construction*of the Rules for Materials.

   (i) Receipt storage and issue of materials, equipment etc.
   (ii) Moulding shop.
   (iii) Care and preparation of mould tools, etc.
   (iv) Lay-up process control.
   (v) Inspection of FRP mouldings on release.
   (vi) Installation of machinery and essential systems.
   (vii) Fitting-out.
   (viii) Tests and trials.
   (ix) Plans and document control.
   (x) Records.

1.6.2 LR's involvement is only in that part of the system which controls the standards required to meet the classification requirements.

1.6.3 The mandatory `documented' quality control system, in general, requires the Builder to have written down procedures that describe clearly and unambiguously how each of the above activities is carried out, when it is carried out and by whom. These procedures will form part of the system manual which is also to contain a statement of management policy, organisation chart and statements of responsibilities. The manual is to be controlled covering formal issue and revision.

1.7 Moulding shop

1.7.1 Where the conventional hand lay-up or spray lay-up processes are used, an even shop temperature of not less than 16°C, and, in general, of not more than 25°C, is to be maintained throughout the moulding area during the lay-up and curing periods. Where the temperature exceeds 25°C, special consideration is to be given to the resin system.

1.7.2 Where moulding processes other than those in *Pt 8, Ch 2, 1.7 Moulding shop 1.7.1* are to be used, the moulding shop temperature will be subject to individual consideration in conjunction with the written recommendations of the manufacturers of the materials.

1.7.3 The relative humidity in the moulding shop is to be kept below 70 per cent, taking into account the dew point, thus avoiding moisture condensation on moulds and materials.

1.7.4 Sufficient temperature and humidity monitoring equipment is to be provided and detailed records are to be kept in accordance with the quality control system.

1.7.5 It is the responsibility of the Builder to ensure that the ventilation and working conditions, together with discharges into the atmosphere, are such that levels of substances are within the limits specified in any pertinent National or International legislation.

1.7.6 The working areas are to be adequately illuminated. Precautions are to be taken to avoid any effects on the resin cure due to direct sunlight or artificial lighting.

1.8 Storage areas

1.8.1 The resins are to be stored under dry, well-ventilated conditions, in accordance with the manufacturer's recommendations.

1.8.2 Where resin tanks or drums are stored outdoors it is the Builder's responsibility to ensure that the resin manufacturer's storage conditions are complied with.

1.8.3 Where the temperature for materials storage drops below that of the moulding shop i.e. minimum 16°C, the materials are to be pre-conditioned to the moulding shop temperature prior to use.

1.8.4 Curing agents are to be stored separately under clean, dry and well-ventilated conditions in accordance with the manufacturer's recommendations and any local or National legislation.

1.8.5 Fillers and additives are to be stored in closed containers that are impervious to dust and moisture.

1.8.6 Reinforcements are to be stored under dust-free and dry conditions.

1.9 Mould construction

1.9.1 Moulds are to be constructed of a suitable material and are to be adequately stiffened to maintain their overall shape and fairness of form.

1.9.2 The materials used in the construction of moulds are not to affect the resin cure.

1.9.3 The finish on a mould is to be such that the mouldings produced are suitable for the purpose intended. The resultant aesthetic appearance of the moulding is strictly a matter between the moulder and the Owner.

1.9.4 Where multiple section moulds are used, the sections are to be carefully aligned to the attending Surveyor's satisfaction prior to moulding. Mismatch between mould sections is to be eliminated.

1.9.5 Where metallic moulds are used, welding is to be minimised to avoid distortion of panels.

1.9.6 The release agent is to be of a type recommended by the resin manufacturer and is not to affect the cure of the resin.

1.9.7 Prior to use all moulds are to be conditioned to the workshop temperature.

1.10 Materials handling

1.10.1 The arrangements for the receipt, verification against certificates of conformity and subsequent handling of materials are to be covered by the Builder's quality control procedures such that the materials do not suffer contamination or degradation and bear adequate identification at all times, *see Ch 14, 3 Testing procedures* of the Rules for Materials. Storage is to be arranged such that materials are used by batch wherever possible, in order of receipt. Materials are not to be used after the manufacturer's date of expiry, except with the prior agreement of LR and new certificates of conformity being obtained from the material manufacturer. Details of the new certificates of conformity are to be entered into the quality control system.

1.10.2 Where materials are found to be non-conforming they are to be rejected in accordance with the Builder's quality control procedure.

1.10.3 All non-conforming materials are to be segregated in their storage areas and marked accordingly.

1.10.4 Resin/catalyst pumps and spray equipment are to be operated in accordance with the manufacturer's instructions. Maintenance and calibration of the mix ratio is to be carried out according to written procedures.

1.11 Faults

1.11.1 All faults are to be classified according to their severity and recorded, together with the remedial action taken, under the requirements of the quality control systems, the documentation being subject to review at the Periodical Survey.

1.11.2 Production faults are to be brought to the attention of the attending Surveyor and a rectification scheme agreed. Deviations from the approved plans are to be to the satisfaction of the attending Surveyor.

1.12 Inspection

1.12.1 It is the Builder's responsibility to carry out the required inspections in accordance with the accepted quality control system.

1.12.2 The Surveyor will monitor the Builder's quality control records and carry out inspections of work in progress during his periodical visits.

1.12.3 During inspections all deviations are to be dealt with under the Builder's agreed quality procedures, *see Pt 8, Ch 2, 1.6 Quality control 1.6.3*.

1.13 Acceptance criteria

1.13.1 Classification is dependent upon the work being carried out in accordance with the approved plans and the requirements of an accepted quality system.

1.13.2 The workmanship is to be to the satisfaction of the attending Surveyor. This will include the verification of the quality control documentation and the remedial action associated with all defects and deficiencies recorded.

1.13.3 Proposed deviations from the approved plans are subject to LR approval. An amended plan is to be submitted to the plan appraisal office, prior to any such changes being introduced.

1.14 Repair

1.14.1 Minor repairs are to be agreed with the attending Surveyor prior to being carried out. The Builder is to incorporate details of the agreed repair procedures in the quality control system in accordance with *Pt 8, Ch 2, 1.6 Quality control 1.6.3*.

1.14.2 Written details of proposed structural repairs are to be submitted to the Plan Approval Office for approval prior to introduction.

1.15 Scaffolding

1.15.1 Scaffolding/platform arrangements are to be provided to permit adequate access for production and inspection purposes. Such arrangements are to conform to National Authority requirements and are not, in general, to be connected to the moulding or impinge on the mould surface.

1.16 Access

1.16.1 The attending Surveyor is to be permitted reasonable access to all areas of the Builder's premises during normal working hours. Scaffolding/platform arrangements are to be made available in accordance with *Pt 8, Ch 2, 1.15 Scaffolding*.

1.17 Lifting arrangements

1.17.1 Lifting arrangements are to be designed such that mouldings are subjected to minimal distortion and unnecessary stressing. Mouldings are to be adequately supported to avoid distortion during final cure.

■ *Section 2* **Materials**

2.1 General

2.1.1 The Rules are applicable to craft generally constructed of fibre reinforced plastic (typically with unsaturated polyester resin), using hand lay-up, mechanical deposition, contact moulding techniques or vacuum assisted techniques. Construction may be either single-skin or sandwich construction, or a combination of both.

2.1.2 Other materials (i.e. non-FRP materials) are to be of good quality, suitable for the purpose intended and, where applicable, are to comply with LR's requirements appropriate to the material. Details of these materials are to be stated on the relevant construction plans. Where these materials are attached to, or encapsulated within, the plastics construction, the material is not to affect adversely the cure of the plastics materials.

2.1.3 Where moulding techniques and methods of construction differing from those given in *Pt 8, Ch 2, 3 General construction process* are proposed, details are to be submitted for consideration by LR.

2.2 Resin system

2.2.1 The resins used are to be of a type that has been approved by LR for marine construction purposes. Samples of the resin batches being used in the construction may be taken for limited quality control examination at the discretion of the Surveyor, *see Ch 14, 5 Control of material quality for composite construction*of the Rules for Materials .

2.2.2 The cure procedure for the resin system is to be that recommended by the resin manufacturer for the particular application, so that the resin will cure in the required time, in accordance with the approved cure schedule.

2.2.3 Wax additives are only to be added by the resin manufacturer in accordance with the agreed procedure and tested accordingly. The base resin is to be of an approved type.

2.2.4 Where a resin contains an ingredient that can settle within the resin system, it is the Builder's responsibility to ensure that the resin manufacturer's recommendations regarding mixing and conditioning are complied with prior to use.

2.3 Compliant resins

2.3.1 Compliant resins for structural applications are to be of types accepted by LR, *see Ch 14, 2.15 Adhesive and sealant materials*, and are to be used strictly in accordance with the manufacturer's recommendations.

2.3.2 Details of the compliant resin to be used in the construction are to be included on the Material Data Sheet at the initial stages of plan approval. The plans submitted for approval are to identify which compliant resins are used in different applications. Surface preparations and over— bonding are also to be identified on the submitted plans.

2.3.3 Proposals for the use of structural filleting applications using compliant resin are to be submitted in detail. Such proposals will be subject to individual consideration.

2.3.4 The acceptance of the use of structural fillets of compliant resins in place of boundary bonding angle laminates required by *Pt 8, Ch 3, 1.19 Boundary bonding*, will be subject to the designer/Builder providing the necessary information and test results to demonstrate equivalence with the Rule requirement for boundary bonding angle laminates.

2.3.5 Air inclusions that may affect the structural efficiency of the joint are to be avoided.

2.4 Resin storage

2.4.1 Bulk storage of resin is to be arranged in accordance with the resin manufacturer's recommendations in suitably adapted and insulated tanks. Tanks and pipes are to be periodically flushed in accordance with the resin manufacturer's recommendations. A ready use store is to be provided where appropriate.

2.5 Gel coats, tie coats and water barriers

2.5.1 Gel coats based on orthophthalic polyester resin systems are not acceptable. All gel coats are to be used strictly in accordance with the manufacturer's recommendations. The curing system is to be in accordance with *Pt 8, Ch 2, 2.2 Resin system 2.2.2*.

2.5.2 Where pigments are to be added reference is to be made to *Pt 8, Ch 2, 2.6 Curing systems*. Where pigments are added by the Builder, the gel coat is to be allowed to stand for sufficient time to permit entrapped air to be released. The method of mixing is to be carried out strictly in accordance with the resin and pigment manufacturer's instructions.

2.5.3 Where the temperature of the gel coat resin is below that of the workshop, the gel coat resin is to be conditioned to attain the workshop temperature prior to use.

2.5.4 Where the inspection of the mould is an agreed hold point, required by the quality plan, the mould is to be inspected by the attending Surveyor prior to gel coating. The Surveyor may also require to witness the initial application of the gel coat, *see also Pt 8, Ch 2, 3.3 Laminating*.

2.5.5 Where a gel coat is not used, details of the proposed water barrier are to be submitted for consideration.

2.5.6 Where a painted finish is to be adopted in place of a gel coat a suitable tie coat may be required in accordance with the paint manufacturer's recommendations.

2.5.7 Where the hull is of sandwich construction built on a male plug mould, the water barrier on the outer surface of the hull will be specially considered.

2.6 Curing systems

2.6.1 Curing systems are to be in accordance with *Pt 8, Ch 2, 2.2 Resin system 2.2.2* and are to be fully compatible with the resins and reinforcements to be used.

2.6.2 For polyester and vinylester resins the level of catalyst and accelerator are to be as recommended by the manufacturer to ensure full polymerisation of the resin. In general, the rate of gelation is to be controlled by the amount of accelerator added to the resin. The amount of catalyst is not to be less than one per cent, by weight, of the base resin.

2.7 Gelation time

2.7.1 The gelation time is to be suitable for the proposed application such that full wet-out of the reinforcement can be obtained without unnecessary drainage on vertical surfaces or excessive loss of the monomer.

2.7.2 The gelation time quoted on the Material Data Sheet is to be the typical gelation time for a laminate as laid in the mould, i.e. the working life of the resin.

2.7.3 The gelation time may need to be varied to suit changing ambient workshop temperatures. For polyester and vinylester resins this is, in general, to be adjusted by variation of the accelerator and not by variation of the catalyst.

2.7.4 All resins are to be mixed in accordance with the resin manufacturer's recommendations.

2.8 Colour pigments

2.8.1 The types of pigment used are to be such that the final cure of the resin is not affected.

2.8.2 The pigment may be added to the resin by either the resin manufacturer or the moulder, and when added by the moulder it is to be as a paste dispersal in the same or compatible resin. Pre-pigmented gel coats are recommended. Where pigments are added by the Builder thorough mixing is essential to avoid striations. *See also Pt 8, Ch 2, 2.2 Resin system 2.2.4* and *Pt 8, Ch 2, 2.3 Compliant resins 2.3.2*.

2.8.3 The amount and type of pigment added is not to exceed that recommended by the resin manufacturer for a satisfactory depth of colour. Proposals to use amounts of pigment solids in excess of five per cent, by weight of the base resin, will be subject to individual approval and testing.

2.8.4 It is recommended that pigments are not to be added to the gel coat or laminating resins used in the underwater portion of the hull laminate or in laminates forming the boundaries of fuel oil and water tanks.

2.8.5 The addition of pigments is not to unduly affect the gelation time of the resin system or the physical properties of the gel coat layer of the laminate produced. The resin and/or pigment manufacturer's written confirmation in this respect is to be obtained and recorded in the Builder's quality control documentation.

2.8.6 The aesthetic appearance of mouldings is strictly a matter between the moulder and the Owner.

2.9 Fillers

2.9.1 All fillers added by a Builder are to be of the dispersed type. The amount of filler that may be added to an approved resin is to be that recommended by the resin manufacturer and is not to alter significantly the viscosity of the resin nor is it to affect the overall strength properties of the laminate. Recommendations by the resin manufacturer to adopt amounts of fillers in excess of 13 per cent by weight of the base resin will be subject to individual approval and testing.

2.9.2 Pigments, thixotropes and fire retardant additives are to be considered as fillers in the calculation of total filler content.

2.9.3 Fillers are to be carefully and thoroughly mixed into the base resin that is then to be allowed to stand to ensure that entrapped air is released. The resin manufacturer's recommendations regarding the method of mixing are to be followed.

2.9.4 Fillers are not to be used in the structural laminates forming the boundaries of fuel oil and water tanks.

2.9.5 Details of all fillers and fire retardant additives are to be included on the Material Data Sheet at the initial stages of plan appraisal.

2.9.6 The amount of fire retardant additives may be in excess of that indicated in *Pt 8, Ch 2, 2.9 Fillers 2.9.1* provided that due account is taken of the reduced mechanical properties when determining scantlings in accordance with the Rules.

2.10 Fire retardant additives

2.10.1 The attention of Owners and Builders is drawn to the additional statutory regulations regarding fire safety that may be imposed by the National Authority of the country in which the craft is to be registered or the Governments of the states to be visited.

2.10.2 For requirements regarding fire safety, *see Pt 17 Fire Protection, Detection and Extinction*.

2.10.3 Where laminates are required to have fire retardant or restricting properties, details of the proposals are to be submitted for approval. Where additives to the resin system are used, the type and quantity are to be as recommended by the resin manufacturer. Test results of independently tested fire retardant and fire restricting materials are to be submitted for design purposes.

2.10.4 All fire retardant resin systems are to be used strictly in accordance with the resin manufacturer's recommendations.

2.10.5 The use of fire retardant and fire restricting materials in craft required to comply with statutory requirements will be subject to the individual approval of the National Authority of the country in which the craft is to be registered, or LR where authorised to undertake this work on behalf of the National Authority.

2.11 Fibre reinforcements

2.11.1 All fibre reinforcements are to be of a type approved by LR.

2.11.2 All reinforcements are to be stored strictly in accordance with the manufacturer's recommendations. Rolls of reinforcement are to remain in their original packaging to minimise contamination. The quality control documentation is to provide traceability of all reinforcements using the manufacturer's batch numbers.

2.11.3 The materials are to be free from imperfections, discolouration, foreign matter and other defects.

2.11.4 Pre-impregnated reinforcements are to be suitably stored in an approved area. Detailed storage records are to be maintained as part of the quality control documentation.

2.12 Surfacing materials

2.12.1 Lightweight surfacing materials for reinforcing resin rich surfaces are to be compatible with the resin being used. Details of the materials and the fibre contents, by weight, are to be included on the Materials Data Sheet (Form 2075).

2.12.2 Where peel ply materials are to be used, the finish is to be such that, after removal, it does not interfere with any subsequent bonding processes.

2.13 Core materials

2.13.1 Core materials for sandwich construction are to be approved by LR, *see Ch 14, 2 Tests on polymers, resins, reinforcements and associated materials*.

2.13.2 All core materials are to be used in accordance with the manufacturer's application procedure, a copy of which is to be submitted for information, with the relevant construction plans of the craft. A second copy is to be incorporated into the quality control documentation.

2.13.3 Rigid expanded foam plastics are to:

(a) be of closed-cell types and impervious to water, fuel and oils;
(b) have good ageing stability;
(c) be compatible with the resin system;
(d) have good strength retention at 60°C;
(e) have characteristics and mechanical properties of not less than those indicated in *Table 2.2.1 Minimum characteristics and mechanical properties of rigid expanded foams at 20°C*; and
(f) if manufactured into formable sheets of small blocks, the open weave backing material and adhesive are to be compatible and soluble, respectively, with the laminating resin.

Table 2.2.1 Minimum characteristics and mechanical properties of rigid expanded foams at 20°C

Material	Apparent density (kg/m^3)	Strength (N/mm^2)			Moduli of elasticity (N/mm^2)	
		Tensile	Compressive	Shear	Compressive	Shear
Polyurethane	96	0,85	0,60	0,50	17,20	8,50
Polvinylchloride	60					

2.13.4 Balsa wood is to:

(a) be end grained;

(b) have been chemically treated against fungal and insect attack and kiln dried shortly after felling;

(c) have been sterilised;

(d) have been homogenised;

(e) have an average moisture content of 12 per cent;

(f) have characteristics and mechanical properties of not less than those indicated in *Table 2.2.2 Minimum characteristics and mechanical properties of end-grain balsa*; and

(g) if manufactured into formable sheets of small blocks, the open weave backing material and adhesive are to be compatible and soluble, respectively, with the laminating resin.

Table 2.2.2 Minimum characteristics and mechanical properties of end-grain balsa

Apparent density (kg/m^3)	Strength (N/mm^2)					Compressive modulus of elasticity (N/mm^2)		Shear modulus of elasticity (N/mm^2)
	Compressive		Tensile		Shear	Direction of stress		
	Direction of stress							
	Parallel to grain	Perpendicular to grain	Parallel to grain	Perpendicular to grain		Parallel to grain	Perpendicular to grain	
96	5,00	0,35	9,00	0,44	1,10	2300	35,20	105
144	10,60	0,57	14,60	0,70	1,64	3900	67,80	129
176	12,80	0,68	20,50	0,80	2,00	5300	89,60	145

2.13.5 Where necessary, foam core materials are to be conditioned in accordance with the manufacturer's recommendations. Conditioning at an elevated temperature, in excess of that which may be experienced in service, may be necessary to ensure the release of any entrapped residual gaseous blowing agents from the cells of the foam core.

2.13.6 Synthetic `felt' type core materials are to be approved in accordance with *Ch 14, 2.10 Synthetic felt type materials with or without microspheres* of the Rules for Materials.

2.13.7 Other types of core materials will be individually considered, on the basis of these Rules in relation to their characteristics and intended application.

2.13.8 Balsa wood is to remain in protective packaging until required in production. Part packages are to be sealed to prevent the ingress of moisture.

2.14 Core bonding materials

2.14.1 Core bonding materials for structural applications are to be of types accepted by LR, and are to be used strictly in accordance with the manufacturer's instructions.

2.14.2 Details of the proposed core bonding paste to be used with the core material are to be indicated on the Materials Data Sheet and the appropriate construction plans.

2.14.3 The Builder is to demonstrate that a uniform thickness of bonding paste is obtained by use of notched trowels or comb gauges. For the use of bonding pastes, *see Pt 8, Ch 2, 4.2 Laminating 4.2.7*.

2.15 Adhesives

2.15.1 Adhesives for structural applications are to be of types accepted by LR, *see Ch 14, 2.15 Adhesive and sealant materials*of the Rules for Materials, and are to be used strictly in accordance with the manufacturer's recommendations.

2.15.2 The details of all structural adhesives are to be specified on the Materials Data Sheet and on the relevant construction plans submitted.

2.15.3 Details concerning the handling, mixing and application of adhesives are to form part of the Builder's production plan.

2.15.4 Particular attention is to be given to the surface preparation and cleanliness of the surfaces to be bonded.

2.15.5 Where excessive unevenness of the faying surfaces exists a suitable gap filling adhesive is to be used or local undulations removed by the application of additional reinforcements.

2.15.6 The Builder's quality plan is to identify the level of training required for personnel involved in the application of structural adhesives.

2.16 Materials for integrated structural members

2.16.1 Metallic materials (such as suitable marine grades of stainless steel or aluminium alloys) used in the construction are to comply with the requirements of *Pt 8, Ch 2, 2.1 General 2.1.2*. Where structural members or components manufactured from these, or other materials, are to be encapsulated within or structurally bonded to laminates, the material is not to adversely affect the cure of the resin system. The surface area of the component that will be in contact with the resin is to be thoroughly cleaned, degreased and, where practicable, either shot blasted or abraded to provide a key.

2.16.2 Where metallic sections are to be bolted into a structure, the bolting requirements are to be determined by direct calculations that are to be submitted for consideration. Appropriate precautions against corrosion are to be taken.

2.16.3 Where plywood and timber members are to be used in structural applications and are to be laminated onto, or encapsulated within the laminate, the surface of the wood is to be suitably prepared and primed prior to laminating.

2.17 Plywood

2.17.1 Plywood, for structural applications, is to be of a high quality marine grade material approved by LR, *see Ch 14, 2.14 Plywoods*. In general, the plywood is to be manufactured to a high standard of finish in accordance with ISO or other Recognised Standards and is to meet, or be equivalent to, the following general requirements:

(a) Have good quality face and core veneers of a durable hardwood species.
(b) The number of veneers is to be in accordance with *Table 2.2.3 Number of veneers*.
(c) The veneers are to be bonded with a WBP (water and boil proof) type adhesive.
(d) Have a moisture content not exceeding 15 per cent.

Table 2.2.3 Number of veneers

Board thickness, mm	Minimum number of plies
up to 9	3
10 to 19	5
20 and above	7

2.17.2 Butts and seams are to be scarfed or butt strapped where necessary. The length of the scarf is to be not less than eight times the plywood thickness. The scarf is to be glued and, if made *in situ*, fitted with a backing strap of width not less than 10 times the panel thickness. The strap is to be glued and fastened with two rows of fastenings of the size given in *Table 2.2.4 Butt strap fastenings* and spaced at approximately eight times the panel thickness.

Table 2.2.4 Butt strap fastenings

Plywood thickness, mm	Breadth of butt strap, mm		Fastenings		
			Wood Screws		Copper boat nails, gauge
			Gauge	Dia., mm	
6	Double fastened	150	8	4,2	10
8		175	10	4,9	10
10		200	10	4,9	8
13		250	12	5,6	8
16		280	12	5,6	6
19	Treble fastened	330	14	6,3	6
22		355	14	6,3	3
25		380	16	7,0	3

Note 1. The gauge of wood screws given in the Table is British Standard Gauge, and that of copper boat nails is Imperial Standard Wire Gauge.

Note 2. The diameter of the wood screw is the nominal diameter of the unthreaded shank.

2.17.3 Butt straps are to be of the width given in *Table 2.2.4 Butt strap fastenings* and the same thickness as the panel. The strap is to be glued and double/treble fastened to the panel. Sizes of fastenings are given in *Table 2.2.4 Butt strap fastenings*.

2.17.4 For further information regarding plywood *see Pt 8, Ch 3, 1.21 Plywood*.

2.18 Timber

2.18.1 The acceptance of timber in the construction will be subject to individual consideration depending upon the intended use and timber involved.

2.18.2 The timber is to be of good quality and properly seasoned. Timber is to be free from heart, sapwood, decay, insect attack, splits, shakes and other imperfections that would adversely affect the efficiency of the material. It is also to be generally free from knots, although an occasional sound intergrown knot would be acceptable.

2.18.3 The moisture content of timber for bonded or overlaminated applications using polyester or epoxy resins is, in general, to be nominally 15 per cent. Contents slightly greater than this value are recommended when resorcinol glues are used, and contents slightly lower than this value are required when phenolic or urea-formaldehyde resins are used.

2.18.4 For further information regarding timber *see Pt 8, Ch 3, 1.20 Timber*.

2.19 Release agents

2.19.1 Release agents are to have no inhibiting effect on the gel coat resin and are to be those recommended by the resin manufacturer.

■ *Section 3* General construction process

3.1 General

3.1.1 Provision is made in this Section for the construction of craft built of fibre reinforced plastic using thermosetting materials. Craft built of fibre reinforced thermoplastic materials will be subject to individual consideration.

3.1.2 This Section contains the general Rule requirements to be complied with in the construction of fibre reinforced craft being built under survey. Where detailed requirements are not defined good boat building practices are to be applied.

3.1.3 Craft built of unusual materials or built using unusual techniques will be subject to individual consideration.

3.2 Resin preparation

3.2.1 Curing agents, fillers and pigments are to be added strictly in accordance with the resin manufacturer's recommendations.

3.2.2 Before decanting, all resins are to be thoroughly mixed, deaerated and conditioned to at shop temperature in accordance with the resin manufacturer's instructions.

3.2.3 All measuring equipment is to be certified and suitable for the quantity of material being measured. Valid certificates of calibration are to form part of the quality control documentation.

3.2.4 Where pumping/metering equipment is used it is to be maintained in accordance with the manufacturer's instructions, and a valid certificate of calibration accuracy is to be retained in the quality control documentation.

3.2.5 Quality control records are to be maintained to provide traceability and identification of the resin and all additives used in the resin system. Batch numbers are to be identified.

3.2.6 Any additive used as a production aid must be that recommended by the resin manufacturer and is not to alter the mechanical properties or the characteristics of the cured laminate.

3.3 Laminating

3.3.1 Production is to follow all necessary approved construction plans in accordance with the LR accepted quality plan.

3.3.2 Laminating is to be carried out by skilled operators, who are to be trained and qualified to the level required by the Builder's quality plan and are to be acceptable to LR.

3.3.3 Moulds are to be thoroughly cleaned, dried and allowed to attain the shop temperature before being treated with a suitable release system, *see also Pt 8, Ch 2, 1.9 Mould construction 1.9.7*.

3.3.4 The gel coat resin is to be applied by brush, roller or spraying equipment to give a uniform, nominal film thickness not exceeding 1,5 mm.

3.3.5 The period of exposure of the gel coat between gelation and the application of the first layer of reinforcement is, in general, to be as short as practicable. In no case is this to be longer than that recommended by the resin manufacturer for that particular resin system. Written confirmation of this is to be obtained and recorded in the Builder's quality control documentation.

3.3.6 Where a polyester or vinylester gel coat is used it is to be reinforced by a lightweight, powder bound reinforcement, generally not exceeding 300g/m^2 in weight, applied at a high resin content to give a glass content, by weight, of not greater than 0,286. This reinforcement is to be consolidated by gentle rolling. Care is to be taken not to damage the gel coat. A surface tissue may be incorporated within the gel coat, the details of which are to be clearly stated in the laminate schedule.

3.3.7 All mouldings are to be manufactured from layers of reinforcement, laid in the approved sequence and orientation, each layer being thoroughly impregnated and consolidated to give the required fibre content, by weight, in accordance with the approved plans.

3.3.8 In composite laminates, containing multiple layers of woven reinforcement, woven reinforcement may be laid on woven reinforcement provided that the inter-laminar shear strength is not less than 13,8 N/mm^2; otherwise, a layer of random fibre reinforcement is to be laid alternately with the woven reinforcements.

3.3.9 Excessive exothermic heat generation caused by thick laminate construction is to be avoided. Where thick laminates are to be laid the Builder is to demonstrate to the Surveyor's satisfaction that the number of plies can be laid wet on wet and that the resultant temperature during the cure cycle does not have any deleterious effect on the mechanical properties of the cured laminate.

3.3.10 Laminating is to be carried out in a sequence such that the time lapse between the application of the successive layers is within the limits recommended by the resin manufacturer and documented in the quality control procedures for the particular resin system. Similarly, the time lapse between the forming and bonding of structural members is to be kept within these limits and, where this is not practicable, the surface of the laminate is to be prepared, in accordance with the resin manufacturer's instructions, to improve the bond.

3.3.11 When laminating is interrupted, and where other than an epoxy resin system is being used, the first of any subsequent layers of reinforcement to be laid in that area is to be of chopped glass fibre or other type of material to enhance the interlaminar strength properties of the laminate.

3.4 Fibre content

3.4.1 To ensure that the resultant thicknesses of the structure is not less than that required to comply with those indicated on the approved plans, the nominal fibre content, by weight, of the individual plies and overall laminate is to be controlled on the basis of the weight of the constituent materials.

3.4.2 Continuous monitoring of resin/reinforcement usage is required for ongoing fibre content verification and is to be recorded under the quality control system, *see Ch 14, 5 Control of material quality for composite construction*of the Rules for Materials.

3.4.3 A method of validating the completed laminate thickness is to be agreed between the Builder and Surveyor. Where electronic thickness measurement methods are employed, the equipment is to be calibrated against a laminate of identical construction. Alternatively a series of areas are to be identified within the craft where samples can be taken to validate the thickness of the laminate (e.g. in way of overboard discharges/ seawater intakes/deck openings etc.).

3.5 Laminate schedule

3.5.1 The laminate schedule is to clearly define the logical sequence of production and is to identify the specific materials to be used.

3.5.2 The schedule is to define the extent of each reinforcement and state relevant details regarding overlapping, staggering thicknesses and tailoring of reinforcements.

3.5.3 Progressive thickness measurements in accordance with *Pt 8, Ch 2, 3.4 Fibre content 3.4.3* are to be recorded as part of the quality control documentation and, where required, additional reinforcements are to be laid to attain the required thickness.

3.5.4 Areas of local deficiency requiring additional reinforcement and areas that have been found to be increased thickness are to be recorded in the quality control documentation.

3.6 Spray laminating

3.6.1 The equipment for spray deposition of resin and glass fibres is to be inspected during the Workshop Inspection and a sample panel produced. Documentary evidence of maintenance, calibration, catalyst content, fibre length and overall fibre content by weight are to be entered into the quality control documentation. The spray pattern is to give an even distribution, as recommended by the manufacturer of the equipment and is to be to the satisfaction of the attending Surveyor.

3.6.2 Special consideration is to be given to the production environment, ventilation equipment and quality control arrangements to ensure that the finished product meets the requirements of the approved plans.

3.6.3 Unless the mechanical properties are confirmed by testing, the chopped fibre length for a structural laminate is to be not less than 35 mm. In no case is the fibre length to be less than 25 mm.

3.6.4 Spray equipment is only to be operated by trained and competent personnel. Training certification is to form part of the quality control documentation. The use of spray lay-up is to be limited to the parts of the structure to which sufficient access can be obtained to ensure satisfactory laminating.

3.6.5 The weights of resin and reinforcement used is to be monitored continuously to check the glass/resin ratio. Samples are also be taken on a regular basis to validate the calibration of the equipment.

3.6.6 Where spray lay-up is used to back up the gel coat the weight of sprayed fibre is not to exceed 300 g/m^2, applied at a high resin content to give a glass content by weight, of not greater than 0,286. This should be consolidated by gentle rolling. This first layer of reinforcement is to be allowed to cure to a trimming state before proceeding with the remainder of the laminate.

3.6.7 Consolidation is to be carried out as soon as is practicable after spray deposition. In general, this is to be carried out when a weight of reinforcement equivalent to a thickness of 2 - 3 mm has been deposited. The thickness of the resulting laminate is to be periodically checked and recorded.

3.6.8 Particular attention is to be given to localised thinning of the laminate in way of chines, coamings, knuckles and openings. Further deposition may be required in such areas to compensate for any reduction in thickness. Alternatively, layers of other equivalent reinforcements may be laid to achieve the required local thickness.

3.7 Release and curing

3.7.1 After completion of the lay-up, the moulding is to be left in the mould for a period to allow the resin to cure before being removed. This period can vary with ambient temperature, the type of resin and the complexity of the moulding, but is to be not less than 12 hours or that recommended by the resin manufacturer.

3.7.2 Care is to be exercised during removal from the mould to ensure that the hull, deck and other large assemblies are adequately braced and supported to avoid damage to and maintain the form of the moulding.

3.7.3 Where female moulds are adopted, all primary stiffening and transverse bulkheads are to be installed prior to removal from the mould unless agreed otherwise on the approved construction schedule and plans.

3.7.4 Mouldings are not to be stored outside of the workshop environment until they have attained the stage of cure recommended by the resin manufacturer for that particular resin. Provision is to be made for mouldings to be protected against adverse weather conditions.

3.7.5 Mouldings are, in general, to be stabilised in the moulding environment for at least 24 hours, or that recommended by the resin manufacturer before the application of any special cure treatment, details of which are to be submitted for approval.

3.8 Barcol hardness

3.8.1 The degree of cure of mouldings is to be measured using a Barcol impressor model GYZJ 934-1 in accordance with BS 2782: Part 10: Method 1001: 1977 (1989) or other equivalent National or International Standard. Alternative equivalent standards of hardness measurement will be considered.

3.8.2 The hardness meter is to be regularly checked for calibration during use. A calibration certificate is to form part of the quality control documentation.

3.8.3 Removal from the mould is not to be attempted until a minimum Barcol reading recommended by the resin manufacturer or a value of 20 has been attained. Subsequently, the moulding is not to be moved outside of the controlled environment until a minimum Barcol reading recommended by the resin manufacturer of 35 (or equivalent) has been recorded.

3.9 Laminate detail

3.9.1 Changes in laminate thickness are to be made using a gradual taper. The length of such taper is, in general, not to be less than 20 times the difference in thickness. Where the construction changes from sandwich laminate to a solid laminate, the thickness of the core material is, in general, to be reduced by a gradual taper of not less than 2:1.

3.9.2 Framing and stiffening sections are to be built up layer by layer in accordance with an approved procedure, particular attention being given to ensure a satisfactory bond and structural continuity at the ends and intersections.

3.9.3 Discontinuities and hard points in the structure are to be avoided, and where the strength of a stiffening member is impaired by any attachment of fittings, openings, drainage arrangements, etc. compensation is to be provided.

3.9.4 Where items are prefabricated outside the mould, they are to be connected by boundary angles formed by layers of reinforcement, structural fillets or other approved method. Where structural fillets are proposed, the scantlings and arrangements will be specially considered.

3.9.5 Polyester, vinylester or epoxide resin may be used in bonded joints, provided that the joint is so designed that the resin bond is in shear. The contact area is to be as large as practicable and the surfaces are to be suitably prepared in accordance with the resin manufacturer's instructions.

3.9.6 The submitted plans are to clearly define the laminate sequence at corner joints. In general, corner laminates are to be boxed and all cuts are to be alternately staggered to avoid a fault line. At corner joints vertical and horizontal laminates are to be laid alternately and butts are to be staggered accordingly.

3.9.7 The submitted plans are to clearly define the details of scarfed joints. In general, scarfs are not to not be steeper than a 12:1 taper. Scarf joints may be either ground or stepped and may be single or double taper. Where single taper scarf joints are proposed, a sealing laminate is to be provided, details of which are to be submitted. Where stepped joints are proposed care is to be taken to ensure that over-cutting does not occur. All joints are to be arranged so that they can be reinforced internally to maintain structural continuity of the laminate.

3.9.8 Lap joints may be bolted or adhesively bonded, or both. They may be single or double lapped dependent upon the specific application.

3.9.9 Where tray mouldings form part of the integral structure of the craft, full details are to be indicated on the submitted plans. Information regarding tolerances is to be presented together with details of all adhesives and proposed bonding-in techniques. Particular attention is to be given to the design so as to maintain the structural continuity of the webs of any stiffening members.

3.9.10 The hulls of all craft with a service speed of 25 knots or greater are to be moulded as required by *Pt 8, Ch 3, 3.15 Hull laminate arrangement*.

3.9.11 Chine details are to be clearly indicated on the submitted plans. Spray rails may form part of the structural laminate or may be installed as a laminated or bolted appendage. Where the chine is a laminated appendage, provision is to be made for a sacrificial ply at which failure may occur without undue damage to the remaining structure of the hull. Sandwich structures are to be returned to single skin laminates at chine rails unless agreed otherwise on the approved construction plans. Chine rails are to be infilled and over laminated on the inner surface of the hull. Additional reinforcement is to be laminated into the chine area in accordance with *Pt 8, Ch 3, 3.8 Chine reinforcement*.

3.9.12 Reinforcements are to be arranged to maintain continuity of strength throughout the laminate. Joints in each layer of reinforcement are, in general, to be overlapped. The length of the overlap is dependent upon the type of reinforcement but is not to be less than 50 mm. The position of the joints in the laminate is to be staggered, in general by 150 mm, to maintain as near uniform laminate thickness as practicable. Tests may be required to demonstrate continuity of strength when bi-directional, multi-axial or cross plied reinforcements are used.

3.9.13 As an alternative to overlapping as required by *Pt 8, Ch 2, 3.9 Laminate detail 3.9.12*, individual consideration will be given, on the basis of test results, to partial butting of reinforcements manufactured with a salvedge. For such reinforcements the salvedge tails are to be laid on top of each other to provide continuity. Butts in the same vertical plane are to be separated by not less than five passing plies.

3.9.14 Laminate overlapping and staggering arrangements may require to be tested at the discretion of the Surveyor.

3.9.15 Laminates may be fastened mechanically provided that the fastenings are of a corrosion resistant metal and are spaced and positioned so as not to impair the efficiency of the joint. The fastenings are to be of an acceptable type and, where washer plates are used, they are to be of a compatible material. The edges of the laminates and the fastening holes are to be sealed.

3.9.16 Where plywood and timber members are to be matted onto, or encapsulated within, the laminate, the surface of the wood is to be suitably prepared prior to bonding.

3.9.17 For details of through hull fittings, *see Pt 8, Ch 2, 5.6 Through hull fittings*.

■ *Section 4*
Additional procedures for sandwich construction

4.1 General

4.1.1 The methods used in sandwich construction are, in general, to be either wet or dry core bonding techniques or by laminating directly onto the core (e.g. plug moulding).

4.2 Laminating

4.2.1 The forefoot and stem of all craft of composite construction are to be moulded as required by *Pt 8, Ch 3, 5.11 Forefoot and stem 5.11.1*.

4.2.2 Where the core material is to be laid onto a pre-moulded skin, it is to be laid as soon as practicable after the laminate cure has passed the exothermic stage.

4.2.3 Where the core is applied to a laminated surface, particular care is to be taken to ensure that a uniform bond is obtained. Where a core is to be applied to an uneven surface, the Surveyor may request additional building up of the surface or contouring of the core to suit.

4.2.4 Where other than epoxy resins are being used, the reinforcement against either side of the core is to be of the chopped strand mat type. Additional flow coating is not to be applied to the foam core prior to laminating.

4.2.5 The submitted plans are to clearly show the staggering of successive plies in both the transverse and longitudinal directions. In general laminates are to be staggered by 50 mm per layer of reinforcement. Where very thin sandwich skins are adopted the rate of laminate stagger will be individually considered.

4.2.6 Prior to bonding, the core is to be cleaned and primed (sealed) in accordance with the manufacturer's recommendations. The primer is to be allowed to cure and is not to inhibit the subsequent cure of the materials contained within the manufacturer's recommended bonding process. The primer is to seal the panels, including all the surfaces between the blocks of contoured material, without completely filling the surface cells.

4.2.7 Where panels of rigid core material are to be used then dry vacuum bagging techniques are, in general, to be adopted. The core is to be prepared by providing `breather' holes to ensure efficient removal of air under the core. Bonding paste is to be visible at such breather holes after vacuum bagging. The number and pitch of such `breather' holes is to be in accordance with the core manufacturer's application procedure and any specific requirements of the core bonding paste manufacturer, *see also Pt 8, Ch 2, 4.4 Vacuum bagging 4.4.3*.

4.2.8 Thermoforming of core materials is to be carried out in accordance with the manufacturer's recommendations. Maximum temperature limits are to be strictly observed.

4.2.9 Where panels of contourable core material are to be used it is necessary to ensure that the core is cut/scored through the entire thickness such that the panels will conform to the desired shape of the moulding. The Builder is to demonstrate that the quantity of bonding material indicated in the core manufacturer's application procedure (*see Pt 8, Ch 2, 2.11 Fibre reinforcements 2.11.2*) is sufficient to penetrate the full depth of the core between the blocks. It is recommended that grid scored panels using a carrier scrim cloth are adopted.

4.2.10 Where the edges of a panel are to be bevelled to single skin the rate of tapering is to be not greater than 30°. In areas where an insert (e.g. higher density foam or plywood) is to be used the rate of taper is not to be greater than 45°.

4.2.11 In all application procedures cured, excess bonding material is to be removed and the panel cleaned and primed prior to the lamination of the final sandwich skin.

4.3 Inserts

4.3.1 Backing or insert pads where fitted in way of the attachment of fittings are to be arranged so that the load can be satisfactorily transmitted into the surrounding structure. The contact area of these pads is to be suitably prepared and free from contamination.

4.3.2 Inserts in sandwich laminates are to be of a material capable of resisting crushing. Inserts are to be well bonded to the core material and to the laminate skins in strict accordance with the approved plans.

4.3.3 Where plywood inserts are to be used all edges are to be bevelled at an angle of 45°. A small gap is to be provided around each insert to ensure the passage of bonding paste during the vacuum bagging process.

4.4 Vacuum bagging

4.4.1 Where wet vacuum bagging is proposed (with or without a core), full details are to be submitted for consideration.

4.4.2 The Builder is to demonstrate by visual inspection that efficient core bonding can be obtained using the proposed dry vacuum bagging process.

4.4.3 The number, size and distribution of breather holes in panels of rigid core material is to be that recommended in the core manufacturer's application procedure, *see Pt 8, Ch 2, 4.2 Laminating 4.2.6*. Typically, 3 mm diameter breather holes are to be provided at 50 mm centres.

4.4.4 The level of vacuum applied for initial consolidation and during the cure period is not to be higher than that recommended by the relevant manufacturer of the materials being used, to avoid the possibility of evaporative boiling and excessive loss of monomer.

■ *Section 5* Details and fastenings

5.1 General

5.1.1 This Section contains the general Rule requirements to be complied with for fibre reinforced plastic craft being built under survey. Where detailed requirements are not defined good boat building practices are to be applied. Where different details are to be applied, the Builder is required to provide evidence of satisfactory service experience or acceptable test data.

5.2 Alignment

5.2.1 Details of alignment and building tolerances are to be laid down in the Builder's production plan.

5.2.2 Where details of alignment and building tolerances are not included on the construction plans, or submitted separately for consideration with the plan submission, they may, subject to individual consideration, be agreed locally with the attending Surveyor.

5.2.3 Particular attention is to be given to the accurate alignment of the following:

(a) girder abutting single skin bulkhead;
(b) girder webs with tank sides;
(c) frames with beams;
(d) deck/bottom girders with bulkhead stiffeners;
(e) tank baffles with floors;
(f) longitudinals where broken at tank ends; and
(g) transom stiffeners with bottom/deck girders.

5.2.4 For larger craft the hull breakage sight-line is to be progressively monitored during the construction of the craft and is to form part of the quality control documentation. The production plan is to identify maximum breakage limits dependent upon the size of the craft.

5.2.5 The production plan is to identify allowable tolerances for the alignment of the primary structural components.

5.2.6 To ensure efficient load transmission intercostal, single skin bulkheads are to be aligned to within half the thickness of the thinner bulkhead. In the case of sandwich construction the tolerance requirements will be individually considered dependent upon the sandwich panel dimensions and the construction of the continuous member. In general, the webs of the intercostal sandwich panel member are to be aligned to within 5 mm. Where poor alignment is identified, additional boundary bonding reinforcements are to be applied as agreed with the attending Surveyor. Such deviations and details of the remedial action taken are to be recorded in the Builder's quality control documentation.

5.2.7 To ensure efficient transmission of shear loads, the alignment tolerance of intercostal `top hat' stiffener webs is, in general, to be within half of the web thickness. Where poor alignment is identified, additional reinforcements are, in general, to be incorporated into the stiffener webs as agreed with the attending Surveyor. Such deviations and details of the remedial action taken are to be recorded in the Builder's quality control documentation.

5.3 Continuity

5.3.1 Continuity of all primary structural members is to be maintained, as required by the Rules, and abrupt changes of section are to be avoided. Both primary and secondary stiffening members are to be continuous unless otherwise agreed with LR.

5.3.2 Special consideration will be given to the intersection of longitudinal and transverse members. In general the ratio between the depths of the intersecting members is to be 2:1. The shallower member is to be continuous under the supporting members.

5.3.3 Alternative proposals to the requirements given in *Pt 8, Ch 2, 5.3 Continuity 5.3.2* will be subject to special consideration in conjunction with the submission of details for maintaining the continuity of reinforcements at intersections in both directions. Where stiffeners are of similar dimensions the primary member is to be continuous. In general the section modulus of the continuous material is to be maintained.

5.4 Openings

5.4.1 All openings are to have well rounded corners and are to be supported on all sides. Cut edges of openings are to be sealed to prevent the ingress of moisture.

5.4.2 All hatch openings are to be supported by a system of transverse and longitudinal stiffeners, the details of which are to be submitted for approval.

5.4.3 The requirements for closing arrangements and outfit are given in *Pt 3, Ch 4 Closing Arrangements and Outfit*.

5.4.4 All deck openings are to have corner radii as specified in *Pt 8, Ch 3, 8.12 Deck openings*.

5.4.5 For details of sealing the edges of openings and sandwich panels, *see Pt 8, Ch 2, 5.10 Exposed edges*.

5.5 Through bolting and bolted connections

5.5.1 The details of all through bolted structural connections are to be indicated on the relevant construction plans submitted for approval. The design of the joint is to be suitable for its intended purpose with a sufficient number of bolts to satisfactorily close the joint.

5.5.2 Tank tops may be bolted down provided the bolt spacing does not exceed $8d_b$, where d_b is the bolt diameter. A joint, seal or stop water is to be fitted, as necessary, to meet the required integrity.

5.5.3 In general, large headed bolts or large diameter thick washers are to be used to prevent localised crushing damage during tightening.

5.5.4 Where mechanical fastenings are used, the torque is to be indicated on the plans submitted for approval.

5.5.5 Bolting arrangements are, in general, to be in accordance with *Pt 8, Ch 2, 5.5 Through bolting and bolted connections*, *Pt 8, Ch 2, 5.6 Through hull fittings*, *Pt 8, Ch 2, 5.7 Backing bars and tapping plates* and *Pt 8, Ch 2, 5.8 Fastenings*. In FRP sandwich construction, inserts of a material capable of resisting crushing are to be fitted in accordance with *Pt 8, Ch 2, 4.3 Inserts*.

5.5.6 The diameter of a fastening is not to be less than the thickness of the thinner component being fastened, with a minimum diameter of 6 mm, excepting window frames where the minimum diameter may be 5 mm.

5.5.7 Bolted connections are, in general, to be bonded along all mating surfaces using an accepted structural adhesive, applied in accordance with the manufacturer's requirements. Where connections rely solely on the shear resistance of the connecting bolts the spacing is not to exceed $3d_b$, where d_b is the diameter of the bolt. In areas where subsequent access will either be limited or not possible, self locking nuts are to be provided.

5.5.8 In general, all structural, bolted connections are to use reeled lines of bolts in accordance with the requirements given in *Table 2.5.1 Bolt pitch requirements in bonded and bolted connections*.

5.5.9 All structural, single line, bolted connections without adhesive bondings are to be in accordance with the requirements given in *Table 4.1.1 Bolt pitch requirements for structural connections* in Pt 3, Ch 4.

Table 2.5.1 Bolt pitch requirements in bonded and bolted connections

Location	Pitch
Watertight connections	$10d_b$
- below static load waterline	
Connections in hull above static load waterline to deck	$15d_b$
Hull to deck connections	
- bonded with structural adhesive	$20d_b$
- bolted with mastic sealant (*see* note 2)	$20d_b$
Connections in deckhouses	$20d_b$
Deckhouse to deck connections	
- bonded with structural adhesive	$20d_b$
- bolted with mastic sealant (*see* note 2)	$20d_b$
Minimum distance between reeled lines of bolts	$3d_b$
Minimum distance from centreline of line of bolts to free edge	$2d_b$

Note 1. d_b is the diameter of the bolt.

Note 2. Internal boundary sealing angle to be provided.

5.5.10 Care is to be taken to avoid distortion of the frame when window frames are bolted into the structure of the craft. Where necessary, uneven surfaces are to be locally built up to the satisfaction of the attending Surveyor.

5.5.11 Where a restricted service notation of G1 or G2 is applicable the requirements given in this Section will be specially considered dependent upon the sea states for which the craft is designed.

5.5.12 Bolt holes are to be drilled, without undue pressure at break through, having a diametric tolerance of two per cent of the bolt diameter. Where bolted connections are to be made watertight the hole is to be sealed with resin and allowed to cure before the bolt is inserted.

5.5.13 In areas of high stress or where unusual bolting configurations are proposed, testing on the basis of equivalence with the above Rules may be required.

5.6 Through hull fittings

5.6.1 Where fittings penetrate the hull envelope, care is to be taken to seal the hull laminate with resin or other suitable compound, *see Pt 8, Ch 2, 5.10 Exposed edges*.

5.6.2 The areas in way of penetrations for fittings in sandwich construction are, in general, to comply with the requirements of *Pt 8, Ch 2, 4.3 Inserts*. Where the requirements cannot be complied with, the core is to be replaced locally with a solid core or very high density foam core with compressive properties commensurate with the loads imposed by the securing arrangements, *see Pt 8, Ch 2, 5.8 Fastenings 5.8.2*. The exposed edges of such openings are to be sealed watertight, *see Pt 8, Ch 3, 3.10 Shell openings*.

5.6.3 All bolted fittings are to be bedded down using a suitable mastic, details of which are to be indicated on the submitted plans.

5.7 Backing bars and tapping plates

5.7.1 The requirements for backing plates and bars will be individually considered, on the basis of the loading imposed, details of which are to be indicated on the submitted plans.

5.7.2 Metallic plates and bars are to comply with the requirements of *Pt 8, Ch 2, 2.1 General 2.1.2* (such as suitable marine grades of stainless steel or aluminium alloys).

5.7.3 Tapping plates may be encapsulated within the laminate, laminated to or bolted to the structure, *see also Pt 8, Ch 2, 2.15 Adhesives 2.15.1*. Where tapping plate edges or corners are likely to give rise to hard spots or stress concentrations the edges are to be suitably rounded.

5.7.4 Where tapping plates are placed on foam cores the plate is to be mounted on a suitable foundation to prevent the movement of the tapping plate during drilling operations.

5.7.5 Direct calculations regarding the scantlings of tapping plates are to be provided at the plan appraisal stage.

5.8 Fastenings

5.8.1 All fastenings are to be of a suitable marine grade. Sizes and specifications are to be indicated on the submitted plans.

5.8.2 In areas where localised crushing of a sandwich core is likely to occur, large diameter washers, compression tubes or inserts or a combination of these are to be adopted.

5.9 Secondary bonding and peel ply

5.9.1 Laminating is to proceed as a continuous process, as far as practicable, with the minimum of delay between successive plies. Where a secondary bond is to be made it is to be carried out in accordance with the resin manufacturer's recommendation, details of which are to be incorporated in the Builder's quality control documentation. This will, in general, take the form of the area being lightly abraded and wiped with a suitable solvent, which is to be allowed to dry prior to laminating.

5.9.2 Where other than epoxy resins are being used, the first reinforcement is to be of the chopped strand mat type.

5.9.3 Consideration should be given, especially in highly stressed areas, to the application of peel ply materials to obviate contamination of the exposed surface, and thereby reducing the abrading required to obtain a good secondary bond.

5.10 Exposed edges

5.10.1 The exposed edges of all openings cut in single skin laminate panels are to be suitably sealed. Where such edges are in wet spaces or under water the edges of such openings are to have rounded edges and are to be sealed by two plies of 450g/m^2 chopped strand mat (or equivalent) reinforcements, *see also Pt 8, Ch 3, 3.10 Shell openings*.

5.10.2 Exposed edges of openings cut in sandwich panels are to be suitably sealed, see *Pt 8, Ch 2, 5.6 Through hull fittings 5.6.2*. The cut edges are, in general, to be sealed with a weight of reinforcement not less than that required for the outer skin of

the sandwich. Where other than an epoxy resin system is used the first layer of such reinforcement is to be chopped strand mat with a weight not exceeding 450 g/m^2, *see also Pt 8, Ch 3, 3.10 Shell openings*.

5.11 Joints

5.11.1 The details of all joints, the proposed jointing procedure and information regarding tolerancing are to be indicated on the submitted plans.

5.11.2 Joints may be bolted or adhesively bonded, or both. Where joints are bolted, full details of the bolt material, the proposed number and spacing are to be provided. Bolts are to be manufactured from a non-corrosive material or protected against corrosion.

5.12 Local reinforcement

5.12.1 Areas subject to local loads or increased stress are to be suitably reinforced, details of which are to be indicated on the submitted plans, *see Pt 8, Ch 3, 3.14 Local reinforcement*.

5.12.2 The design of the structure, in way of the attachment of fittings or equipment in sandwich structures, is to be such that the induced loads can be transmitted into the surrounding structure by bending as opposed to shear. The areas are, in general, to take the form of suitably reinforced single skin areas, *see Pt 8, Ch 3, 3.14 Local reinforcement*, with the additional layers of reinforcement staggered out onto the surrounding inner and outer skins as indicated in *Figure 3.3.1 Single skin/sandwich skin intersection detail*.

5.13 Hull to deck connections

5.13.1 Details of the hull to deck connection, the method of bonding and the tolerances are to be indicated on the submitted plans.

5.13.2 Hull to deck connections should, in general, be bolted and over-bonded. A suitable mastic or sealing compound is to be incorporated within the joint.

5.13.3 The bolting details should be reeled lines of bolts pitched as specified in *Table 2.5.1 Bolt pitch requirements in bonded and bolted connections*. Suitable large diameter thick washers should be used under both the head and the nut.

5.13.4 Where a mastic is not used, sealing plies are to be applied on the inside of the hull.

5.13.5 The weight of the over-bonding reinforcement is, in general, not to be taken as less than equivalent to the lighter of the component members being connected, and in no case less than equivalent to three plies of 600 g/m^2 chopped strand mat.

5.13.6 Substantial beam knees are to be provided to maintain structural continuity between the transverse deck and hull stiffening.

5.13.7 The watertight integrity, continuity and strength of the connection is not to be impaired by the attachment of the hull fender.

5.13.8 For guidance details of scantlings required to resist impact loads at deck edge connections *see Pt 8, Ch 3, 4.19 Fenders and reinforcement in way* for side shell in way of fendering and *Pt 8, Ch 3, 3.6 Sheerstrake* for sheerstrakes.

5.14 Exhaust systems

5.14.1 Exhaust systems, manufactured from FRP, are to be of the water injected type with a normal operating temperature of 60° - 70°C and a maximum operating temperature of 120°C.

5.14.2 Exhaust pipes, silencers and water separators should be of a Type Approved design, installed strictly in accordance with the manufacturer's requirements.

5.14.3 Where a Type Approved system is not used, the arrangement will be considered on an individual basis. Resins used in the manufacture of exhaust systems are to be of a type approved by LR and are to have good heat and chemical resistance properties with a high deflection temperature under load. A vinylester resin should be used, but a fire retardant polyester resin, having a high heat distortion temperature, will be considered. Test samples may be required dependent upon the proposed arrangement, temperatures and materials.

5.14.4 It is recommended that pigments and additives are not used unless it can be demonstrated that the mechanical properties of the resin system remain unaffected. Resins used are not to show any embrittlement with age.

5.14.5 Special consideration is to be given to post curing of such systems to obtain optimal characteristics.

5.14.6 Due to the weight of water contained within the system, exhaust pipes and fittings are to be efficiently supported.

5.14.7 Exhaust boxes are to be lined with a minimum of two plies of 600g/m^2 chopped strand mat (or equivalent) using a suitable fire retardant/high temperature resin.

5.14.8 For engineering aspects of exhaust systems reference is to be made to *Pt 10, Ch 1, 8.3 Exhaust systems*.

5.14.9 National Authority requirements take precedence over the requirements given in this Section.

5.15 Ballast

5.15.1 The provision of permanent ballast is not to adversely affect the surrounding structure.

5.15.2 Where a resin compound is to be poured into a void space, care is to be taken to minimise the generation of heat that may affect the mechanical and weathering characteristics of the structural laminate.

5.15.3 Details of all ballast materials and the proposed method of installation are to be indicated on the submitted plans.

5.16 Limber holes

5.16.1 Provision is to be made to drain areas likely to accumulate liquids, details of which are to be indicated on the submitted plans.

5.16.2 The size, shape and position of limber holes are not to affect the structural strength of the stiffening members in which they are fitted. Limber holes are, in general, to be positioned at the quarter span of the stiffener.

5.17 Integral tanks (requirements for coatings)

5.17.1 The surfaces of integral tanks are to be provided with a barrier to reduce the ingress of liquid. The details of the proposed system are to be indicated on the submitted plans.

5.17.2 Fresh water tanks are to be coated with a non-toxic and non-tainting coat of resin that is recommended by the resin manufacturer for potable water tanks.

5.17.3 The design and arrangement of fuel oil tanks is to be such that there is no exposed horizontal section at the bottom that could be exposed to a fire. Other fire protection arrangements for fuel oil tanks will be specially considered. For details of fire protection requirements *see Pt 17 Fire Protection, Detection and Extinction*.

5.17.4 Where plywood bulkheads form part of a tank boundary, the surface is to be completely protected against the ingress of moisture with a minimum of 4 mm thickness of laminate to provide an effective fluid barrier, regardless of resin and reinforcement type used.

5.17.5 Where outfit items are to be laminated to the tank surface, the heavy coating of resin is to be applied afterwards and the laminated brackets sealed to prevent the ingress of moisture.

5.17.6 The scantlings of integral fuel oil and water tanks are to be in accordance with *Pt 8, Ch 3, 7 Bulkheads and deep tanks*. Details regarding sub-division of integral tanks are given in *Pt 8, Ch 3, 7.11 Wash plates 7.11.1*.

5.17.7 Integral tanks are to be tested in accordance with *Pt 8, Ch 3, 7.17 Testing*.

5.18 Reserve buoyancy

5.18.1 Details of materials to be used and the method of installation of reserve buoyancy are to be indicated on the submitted plans.

5.18.2 Where necessary, buoyancy materials are to be over-laminated *in situ* to prevent the ingress of moisture.

5.19 Shear ties (stiffeners)

5.19.1 Where the total web depth to thickness ratio requirement in *Pt 8, Ch 3, 1.17 Stiffener proportions* for buckling of stiffener webs is not complied with, cross linking of the stiffener webs at the Rule depth to thickness ratio is to be provided by the use of shear ties, as indicated in *Figure 2.5.1 Arrangement of shear ties (stiffeners)*.

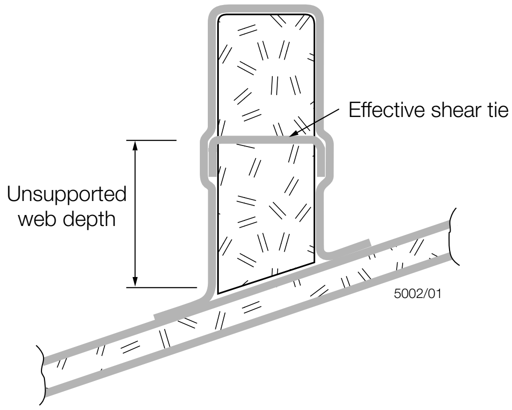


Figure 2.5.1 Arrangement of shear ties (stiffeners)

5.19.2 Alternative arrangements will be subject to individual consideration in conjunction with submitted direct calculations.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull craft of composite construction as defined in *Ch 1, 1 Background*.

1.2 General

1.2.1 The scantlings of motor and sailing, mono-hull craft of conventional form and proportions are to be determined from the formulae contained within this Chapter.

1.2.2 The mechanical properties to be used for scantling calculation purposes are to be 90 per cent of the mean first ply/resin cracking failure values determined from accepted mechanical tests, or the mean values minus twice times the standard deviation for the five samples, whichever is the lesser. All test pieces are to be representative of the product to be manufactured and details submitted for consideration.

1.2.3 In the absence of suitable test data, the mechanical properties of the materials is to be estimated from the appropriate procedures and formulae contained within this Part. The acceptable design values for glass reinforced polyester resin laminates are, in general, not to be taken greater than those determined from *Table 3.1.1 Mechanical properties for chopped strand mat (CSM) glass reinforced polyester resin laminates* to *Table 3.1.3 Mechanical properties for uni-directional glass reinforced polyester resin laminates at 0/90° degree orientation*. Additional information on the application of the various formulae is given in Lloyd's Register's (hereinafter referred to as 'LR') *Guidance Notes for Calculation Procedures for Composite Construction*.

Table 3.1.1 Mechanical properties for chopped strand mat (CSM) glass reinforced polyester resin laminates

Mechanical property	N/mm^2
Ultimate tensile strength	$200 f_c + 25$
Tensile modulus	$(15 f_c + 2) \times 10^3$
Ultimate compressive strength	$150 f_c + 72$
Compressive modulus	$(40 f_c - 6) \times 10^3$
Ultimate shear strength	$80 f_c + 38$
Shear modulus	$(1{,}7 f_c + 2{,}24) \times 10^3$

Ultimate flexural strength	502 f_c^2 + 106,8
Flexural modulus	(33,4 f_c^2 + 2,2) x 10^3
Note f_c is as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*.	

Table 3.1.2 Mechanical properties for woven roving (WR) and cross-plied (CP) glass reinforced polyester resin laminates at 0/90° degree orientation

Mechanical property	N/mm^2
Ultimate tensile strength	400 f_c - 10
Tensile modulus	(30 f_c - 0,5) x 10^3
Ultimate compressive strength	150 f_c + 72
Compressive modulus	(40 f_c - 6) x 10^3
Ultimate shear strength	80 f_c + 38
Shear modulus	(1,7 f_c + 2,24) x 10^3
Ultimate flexural strength	502 f_c^2 + 106,8
Flexural modulus	(33,4 f_c^2 + 2,2) x 10^3
Note f_c is as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*.	

1.2.4 In the absence of suitable test data, the mechanical properties of aramid and carbon reinforced epoxy resin laminates are, in general, not to be taken greater than those determined from *Table 3.1.3 Mechanical properties for uni-directional glass reinforced polyester resin laminates at 0/90° degree orientation*.

Table 3.1.3 Mechanical properties for uni-directional glass reinforced polyester resin laminates at 0/90° degree orientation

Mechanical property	N/mm^2
Longitudinal elastic modulus	(50,5f_c – 6,87) x 10^3
Transverse elastic modulus	(19,6f_c^2 – 15,7f_c + 6,6) x 10^3
In-plane shear modulus	(7,3f_c^2 – 5,9f_c + 2,4) x 10^3
Longitudinal tensile strength	656f_c – 89,3
Longitudinal compressive strength	530f_c – 72,1
Transverse tensile strength	68,4f_c^2 – 55f_c + 23
Transverse compressive strength	196f_c^2 – 157f_c + 65,6
In-plane shear strength	73,4f_c^2 – 59,2f_c + 24,5
Note 1. f_c is as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*. **Note** 2. Range of applicability: 0,4 < f_c < 0,7. Laminates with fibre contents outside range of applicability will be specially considered.	

Table 3.1.4 Mechanical properties for uni-directional aramid reinforced epoxy resin laminates at 0/90° degree orientation

Mechanical property	N/mm^2
Longitudinal elastic modulus	(91,2f_c + 1,1) x 10^3
Transverse elastic modulus	(1,5f_c + 2,4) x 10^3
In-plane shear modulus	(8,6f_c^2 – 6,1f_c + 2,6) x 10^3

Longitudinal tensile strength	$1186 f_c + 14,3$
Longitudinal compressive strength	$319 f_c + 3,8$
Transverse tensile strength	$7,5 f_c + 12,1$
Transverse compressive strength	$22,4 f_c + 36,4$
In-plane shear strength	$129 f_c^2 – 92 f_c + 38,4$

Note 1. f_c is as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*.

Note 2. Range of applicability: $0,25 < f_c < 0,55$. Laminates with fibre contents outside range of applicability will be specially considered.

Table 3.1.5 Mechanical properties for woven roving (WR) and cross-plied (CP) aramid reinforced epoxy resin laminates at 0/90° degree orientation

Mechanical property	N/mm^2
Elastic modulus	$(46,4 f_c + 1,76) \times 10^3$
In-plane shear modulus	$(8,6 f_c^2 – 6,1 f_c + 2,6) \times 10^3$
Tensile strength	$596 f_c + 13,2$
Compressive strength	$171 f_c + 20,1$
In-plane shear strength	$129 f_c^2 – 92 f_c + 38,4$

Note 1. f_c is as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*.

Note 2. Range of applicability: $0,25 < f_c < 0,55$. Laminates with fibre content outside range of applicability will be specially considered.

Table 3.1.6 Mechanical properties for uni-directional carbon reinforced epoxy resin laminates at 0/90° degree orientation

Mechanical property	N/mm^2
Longitudinal elastic modulus	$(153 f_c – 9,80) \times 10^3$
Transverse elastic modulus	$(5,8 f_c^2 – 2,6 f_c + 3,5) \times 10^3$
In-plane shear modulus	$(8,9 f_c^2 – 6,6 f_c + 2,7) \times 10^3$
Longitudinal tensile strength	$1377 f_c – 88,2$
Longitudinal compressive strength	$842 f_c – 53,9$
Transverse tensile strength	$21,7 f_c + 7,5$
Transverse compressive strength	$65,2 f_c + 22,4$
In-plane shear strength	$132 f_c^2 – 99,5 f_c + 40$

Note 1. f_c is as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*.

Note 2. Range of applicability: $0,3 < f_c < 0,6$. Laminates with fibre content outside range of applicability will be specially considered.

Table 3.1.7 Mechanical properties for woven roving (WR) and cross-plied (CP) carbon reinforced epoxy resin laminates at 0/90° degree orientation

Mechanical property	N/mm^2
Elastic modulus	$(78{,}7f_c – 4{,}15) \times 10^3$
In-plane shear modulus	$(8{,}8f_c^2 – 6{,}6f_c + 2{,}7) \times 10^3$
Tensile strength	$690f_c – 35{,}3$
Compressive strength	$453f_c – 15{,}7$
In-plane shear strength	$132f_c^2 – 99{,}5f_c + 40$
Note 1. f_c is as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*.	
Note 2. Range of applicability: $0{,}3 < f_c < 0.6$. Laminates with fibre content outside range of applicability will be specially considered.	

1.2.5 The various formulae referred to in *Pt 8, Ch 3, 1.2 General 1.2.3* and *Pt 8, Ch 3, 1.2 General 1.2.4* require that sufficient input data be available which relates to each of the proposed materials. The designers and/or Builders are to, in general, agree the values for use in the scantling analysis with LR at the design stage and prior to the submission of plans and data for appraisal.

1.2.6 Typical acceptable values for the various fibre properties of materials commonly in use are given in *Table 3.1.8 Typical minimum fibre properties*.

Table 3.1.8 Typical minimum fibre properties

	Specific gravity ζ_F	Tensile modulus N/mm^2	Shear modulus N/mm^2	Poisson's ratio μ_F
E glass	2,56	69000	28000	0,22
S glass	2,49	69000	- *see* Note 3	0,20
R glass	2,58	- *see* Note 3	- *see* Note 3	- *see* Note 3
Aramid	1,45	124000	2800	0,34
LM graphite *see* Note 1	1,80	230000	- *see* Note 3	- *see* Note 3
IM graphite *see* Note 1	1,80	270000	- *see* Note 3	- *see* Note 3
HM graphite *see* Note 1	1,8	300000	- *see* Note 3	- *see* Note 3
IM graphite *see* Note 2	1,9	160000	- *see* Note 3	- *see* Note 3
HM graphite *see* Note 2	2,0	380000	- *see* Note 3	- *see* Note 3
VHM graphite*see* Note 2	2,15	725000	- *see* Note 3	- *see* Note 3
Note 1. Polyacryonitrile type.				
Note 2. Mesophase pitch precursor type.				
Note 3. Actual values to be obtained from the material manufacturer and are to be agreed with LR prior to use.				

1.2.7 Typical acceptable values for the various resin properties of materials commonly in use are given in *Table 3.1.9 Typical minimum resin properties*.

Table 3.1.9 Typical minimum resin properties

	Type	Specific gravity ζ_R	Tensile modulus N/mm^2	Shear modulus N/mm^2	Poisson's ratio γ_R
Polyester	Thermosetting	1,20	3400	1300	0,36
Vinylester	Thermosetting	1,44	3500	- *see* Note	- *see* Note
Epoxy	Thermosetting	1,38	3500	- *see* Note	0,39
Phenolic	Thermosetting	1,30	1500-2500 *see* Note	- *see* Note	- *see* Note
Note Actual value to be obtained from the material manufacturer and is to be agreed with LR prior to use.					

1.3 Direct calculations

1.3.1 The scantlings are to be determined by direct calculation where the craft is of unusual design, form or proportions, or where the speed of the craft exceeds 60 knots.

1.3.2 The requirements of this Section may be modified where direct calculation procedures are adopted to analyse the stress distribution in the primary structure.

1.4 Equivalents

1.4.1 LR will consider direct calculations for the derivation of scantlings as an alternative and equivalent to those derived by Rule requirements in accordance with *Ch 2, 3 Impact tests*of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

1.5 Symbols and definitions

1.5.1 The symbols used in this Chapter, unless specified otherwise, are defined as follows:

B = moulded breadth of the craft, in metres

b = unsupported panel breadth, in mm

b_i = breadth of individual ply, i, in mm

e_f = flexural strain of plate laminate

E_{ci} = compressive modulus of individual ply, i, in N/mm^2

E_{cp} = compressive modulus of plate laminate, in N/mm^2

E_i = E_{ti} or E_{ci} for the ply relative to its position above or below the neutral axis

E_F = tensile modulus of the fibres, in N/mm^2

E_R = tensile modulus of the resin, in N/mm^2

E_{ti} = tensile modulus of individual ply, i, in N/mm^2

E_{cps} = compressive modulus of the sandwich skin plate laminate as determined from *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.5*, in N/mm^2

E_{tps} = tensile modulus of the sandwich skin plate laminate as determined from *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.4*, in N/mm^2

E_{fp} = flexural modulus of plate laminate, in N/mm^2

E_{tp} = tensile modulus of the plate laminate, in N/mm^2

f_c = the fibre content, by weight, within the laminate

f_{ci} = fibre content, by weight, of individual ply, *i*

G = shear modulus of sandwich core material, in N/mm^2

I_i = second moment of area for a 1 cm length of the cross section of individual ply, *i*, in cm^4

I_P = second moment of area for a 1 cm length of the cross section of plate laminate, in cm^4

k_A = $85/\sigma_u$

k_s = sandwich laminate aspect ratio correction factor, as defined in *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.9*

L_R = Rule length of craft, in metres

M = bending moment, as appropriate, in Nm

l_e = effective span length of stiffener, in metres

σ_u = ultimate tensile strength of the plate laminate, in N/mm^2

p = design pressure in kN/m^2, as calculated in *Pt 5 Design and Load Criteria* for the appropriate item

s = stiffener spacing, in mm

t_c = core thickness, in mm

t_i = thickness of individual ply, *i*, in mm

t_p = thickness of plate laminate, in mm

t_s = mean skin thickness, in mm

υ_F = Poisson's ratio for the fibre

υ_R = Poisson's ratio for the resin

V_{Fi} = volume fraction of fibres of individual ply, *i*

W_{Fi} = weight fraction of the fibres of individual ply, *i*

m_{Fi} = mass of reinforcement in individual ply, *i*, in g/m^2

x_i = distance to the centre of individual ply, *i*, from the plate or sandwich laminate surface, in mm

x_L = distance of the neutral axis from the surface of the plate or sandwich laminate, in mm

x_S = the distance of the neutral axis, from the outer surface of the plate or sandwich laminate

y_i = distance from the neutral axis to the outer extremity of an individual ply, *i*, in mm

σ_{ci} = maximum compressive stress within ply, *i*, in N/mm^2

σ_{ti} = maximum tensile stress within ply, *i*, in N/mm^2

ζ_{Fi} = specific gravity of reinforcement in individual ply, *i*

ζ_{Ri} = specific gravity of resin in individual ply, *i*.

1.5.2 The side shell is defined as the portion of the hull between the bottom shell and the deck at side.

1.6 Material properties

1.6.1 The nominal thickness of an individual ply, t_i, may be determined from:

$$t_i = \frac{m_{Fi}\left[\frac{\zeta_{Fi}}{f_{ci}} - \left(\zeta_{Fi} - \zeta_{Ri}\right)\right]}{1000\,\zeta_{Fi}\,\zeta_{Ri}} \text{ N/mm}^2$$

where f_{ci}, t_i, m_{Fi}, ζ_{Fi} and ζ_{Ri} are as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*

1.7 Effective width of attached plating

1.7.1 The geometric properties of stiffening sections are to be calculated in accordance with *Pt 8, Ch 3, 1.16 Geometric properties stiffener sections* using an effective width, $2b_1$, of attached load bearing plating determined as follows:

(a) Single skin construction:

$b_1 = 0{,}5b_w + 10\,t_{ap}$

(b) Sandwich skin construction:

Generally:

$b_1 = 0{,}5b_w + 10(t_{outer} + t_{inner})$

Where a plywood core is used:

$b_1 = 0{,}5b_w + 10(t_{outer} + t_{inner} + 0{,}5\,t_{ply})$

where

b_1 = effective width of attached load bearing plating, in mm, and is not to be taken as greater than one half the spacing between the centres of adjacent stiffeners

b_w = base width of the stiffener section, in mm

t_{ap} = thickness, or mean thickness of attached plate laminate, in mm

t_{inner} = thickness, or mean thickness of inner skin laminate, in mm

t_{outer} = thickness, or mean thickness of outer skin laminate, in mm

t_{ply} = thickness of plywood core, in mm

1.7.2 The geometric properties of primary support members (i.e. girders, stringers, web frames, etc.) are to be calculated in accordance with *Pt 8, Ch 3, 1.16 Geometric properties stiffener sections* using an effective area of attached load bearing plate laminate of nominal thickness, *t* mm, and of width equal to one-half the sum of spacings between parallel adjacent members or equivalent support.

1.8 Glass fibre and advanced fibre composites

1.8.1 Strength calculations for all advanced fibre composites are to be based on the results of testing of truly representative sections of the proposed design. In general the sections are to be manufactured under typical production conditions using the same materials, fibre contents, methods of lay-up and time delays.

1.8.2 Mechanical testing is, in general, to be based upon the requirements of *Ch 14, 3 Testing procedures* of the Rules for Materials.

1.8.3 Where test data is not available for standard glass fibre laminates, the following theoretical approach is to be used to estimate the tensile modulus and the shear modulus of a laminate:

The tensile modulus of a uni-directional reinforcement at angle θ to the axis of the fibres is to be determined from:

$$E_{\theta \mathrm{i}} = \frac{E_{0\mathrm{i}}}{cos^4 \theta_{\mathrm{i}} + \frac{E_{0\mathrm{i}}}{E_{90\mathrm{i}}} sin^4 \theta_{\mathrm{i}} + \frac{1}{4}\left(\frac{E_{0\mathrm{i}}}{G_{0/90\mathrm{i}}} - 2u_{0/90\mathrm{i}}\right) sin^2 2\theta_{\mathrm{i}}} \text{ N/mm}^2$$

where

θ_i = angle of orientation of the fibre relative to the warp direction, and is not to be taken as less than seven degrees to allow for misalignment

E_{0i}, the longitudinal tensile modulus of individual ply, *i*, for an unfilled resin system is determined from:

$$E_{0\mathrm{i}} = E_{\mathrm{F}} V_{\mathrm{F}} + E_{\mathrm{R}}\left(1 - V_{\mathrm{F}}\right) \text{ N/mm}^2$$

E_F, V_F and E_R are as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*

V_F, the volume fraction of the fibres of individual ply, *i*, is determined from:

$$V_{\mathrm{F}} = \frac{W_{\mathrm{F}} z_{\mathrm{R}}}{W_{\mathrm{F}} z_{\mathrm{R}} - W_{\mathrm{F}} z_{\mathrm{F}} + z_{\mathrm{F}}}$$

W_F, ζ_F and ζ_R are as indicated in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*

E_{90i}, the transverse tensile modulus of individual ply, *i*, is determined from:

$$E_{90\mathrm{i}} = \frac{E_{\mathrm{F}} E_{\mathrm{R}}}{E_{\mathrm{R}} V_{\mathrm{F}} + E_{\mathrm{F}} - E_{\mathrm{F}} V_{\mathrm{F}}} \quad \text{N/mm}^2$$

E_F, E_R and V_F are as indicated in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*.

$G_{0/90i}$, the shear modulus of individual ply, *i*, is determined from:

$$G_{0/90i} = G_{\mathrm{R}}\left(\frac{\frac{G_{\mathrm{F}}}{G_{\mathrm{R}}}\left(1 + V_{\mathrm{F}}\right) + \left(1 - V_{\mathrm{F}}\right)}{\frac{G_{\mathrm{F}}}{G_{\mathrm{R}}}\left(1 - V_{\mathrm{F}}\right) + \left(1 + V_{\mathrm{F}}\right)}\right) \text{N/mm}^2$$

Where the shear modulus of the resin, G_R is determined from:

$$G_{\mathrm{R}} = \frac{E_{\mathrm{R}}}{2\left(1 + \upsilon_{\mathrm{R}}\right)} \text{ N/mm}^2$$

Where the shear modulus of the fibre, G_F is determined from:

$$G_{\mathrm{F}} = \frac{E_{\mathrm{F}}}{2\left(1 + \upsilon_{\mathrm{F}}\right)} \text{ N/mm}^2$$

E_F, E_R, ν_R and ν_F are as indicated in *Pt 8, Ch 3, 1.5 Symbols and definitions*.

The longitudinal Poisson's ratio, $\nu_{0/90}$, of individual ply, *i*, is determined as follows:

$$\upsilon_{0/90} = V_{\mathrm{F}}\left(\upsilon_{\mathrm{F}} - \upsilon_{\mathrm{R}}\right) + \upsilon_{\mathrm{R}}$$

V_F, ν_F and ν_R are as indicated in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*.

1.8.4 Where specific test data is not available for glass fibre reinforced polyester laminates, the mechanical properties for design are to be the values determined from the formulae given in *Table 3.1.1 Mechanical properties for chopped strand mat (CSM) glass reinforced polyester resin laminates* and *Table 3.1.2 Mechanical properties for woven roving (WR) and cross-plied (CP) glass reinforced polyester resin laminates at 0/90° degree orientation*.

1.9 Plate and sandwich laminates

1.9.1 Unless otherwise specified in this Part, the bending moments, M_b and M_c, to be applied to a 1 cm length of panel, for both plate and sandwich laminates, subjected to lateral pressure are to be determined from:

(a) Bending moment at panel boundary and under base of stiffener, M_b:

$$M_b = \frac{k\ pb^2}{12} \times 10^{-5} \text{ Nm}$$

(b) Bending moment at centre of panel, M_c:

$$M_c = \frac{(1,5 - k)pb^2}{12} \times 10^{-5} \text{ Nm}$$

where

$k = \dfrac{\gamma^3 + 1}{\gamma + 1}$

$\gamma = \dfrac{b_w}{b}$

= $b_w < b$ and is as defined below, *see Figure 3.1.1 Panel dimensions*:

b = unsupported panel breadth, in mm

b_w = base width of stiffener, in mm

γ = ratio of base width of stiffener to panel breadth

k = bending moment influence coefficient

l_p = panel length, in mm

ρ = for bottom and side shell of craft operating in non-displacement mode the greater of:

= (a) $H_f S_f P_s$;

= (b) $K_i H_f S_f C_f P_{dl}$;

= (c) $H_f S_f G_f C_f P_f$;

= in kN/m^2, where H_f, S_f, G_f, C_f, P_s, P_{dl}, P_f are as defined in *Pt 5, Ch 3, 2 Nomenclature and design factors*, and K_i as defined in *Pt 8, Ch 3, 1.12 Slamming Pressure Correction*.

= For all other locations the design pressure is to be taken as required by *Pt 5 Design and Load Criteria* for the element of plate laminate under consideration, in kN/m^2.

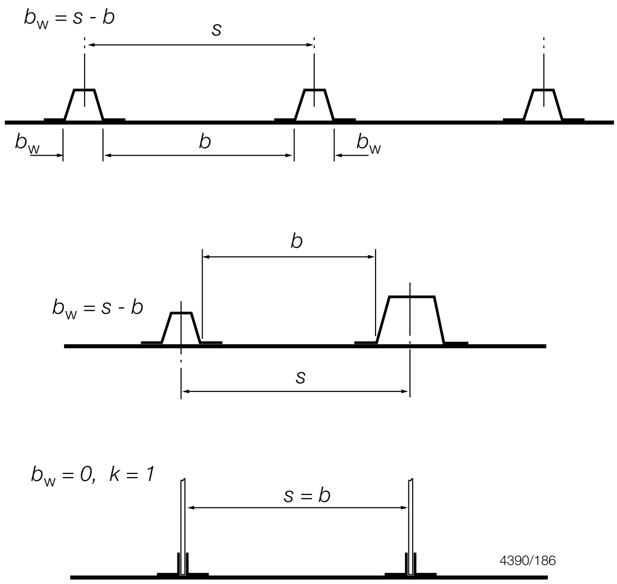


Figure 3.1.1 Panel dimensions

1.10 Aspect ratio correction

1.10.1 The Rule bending moments, M_b and M_c, to be applied to plate laminates as determined by *Pt 8, Ch 3, 1.9 Plate and sandwich laminates 1.9.1*, may be reduced when the panel aspect ratio is taken into consideration. For panels with aspect ratio less than two the following factor, K_{AR}, may be applied:

$$K_{AR} = 0,56 + 0,63\, ln(A_R) \geq 0,56$$

where

A_R = panel aspect ratio

= panel length/panel breadth

1.11 Convex curvature

1.11.1 The Rule bending moments, M_b and M_c, as determined by *Pt 8, Ch 3, 1.9 Plate and sandwich laminates 1.9.1*, may be reduced where significant curvature exists between the support members. For such panels the following factor, K_c, may be applied:

$$K_c = 1 - 1,76\frac{h}{s} \geq 0,56$$

where

h = the distance, in mm, measured perpendicularly from the chord length s (i.e. spacing) to the highest point of the curved plating arc between the two supports, *see Figure 3.1.2 Convex curvature*.

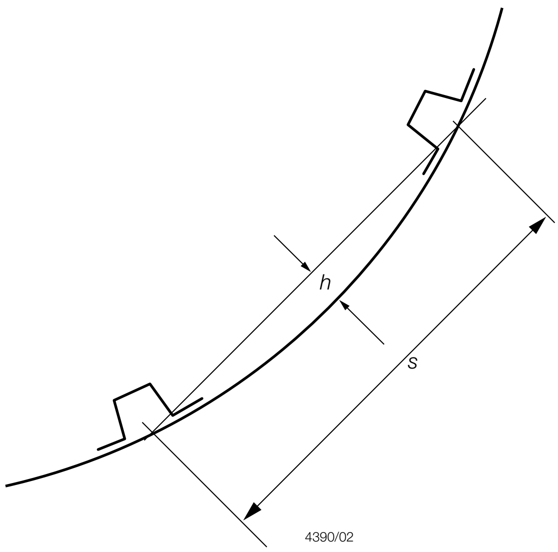


Figure 3.1.2 Convex curvature

1.12 Slamming Pressure Correction

1.12.1 The Rule bending moments, M_b and M_c, as determined by *Pt 8, Ch 3, 1.9 Plate and sandwich laminates 1.9.1*, may be reduced for panels subject to impact pressure, P_{dl}, in crafts operating in the non-displacement mode. For such panels, the following factor, K_i, may be applied:

$$K_i = 0,18 + \frac{1,8}{16\left(\frac{A_{pn}}{A_{rf}}\right) + 1,1}$$

but is not to be taken greater than 1 or less than 0,7

Apn = area of plate laminate, in m^2, but is not to be taken as

greater than $2\left(\frac{s}{1000}\right)^2$

A_{rf} = reference impact pressure area, in m^2,

= $0,7\,\frac{\Delta}{T}$

= displacement, in tonnes, as defined in *Pt 5, Ch 2, 2.2 Symbols 2.2.2*

T = draught, in metres, as defined in *Pt 3, Ch 1, 6.2 Principal particulars 6.2.9*

s = is as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*

1.13 Determination of properties and stresses for single skin plate laminates

1.13.1 An estimate of the thickness of single skin plating required to carry the bending moment given in *Pt 8, Ch 3, 1.9 Plate and sandwich laminates 1.9.1*, is to be determined from:

$$t = 0,146\, b \sqrt[3]{\frac{p}{E_{tp}}} \text{ mm}$$

where b, p and E_{tp} are as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*.

1.13.2 The distance of the neutral axis, x_L, from the surface of the plate laminate is to be determined from the following:

$$x_L = \frac{\Sigma\left(E_i t_i x_i\right)}{\Sigma\left(E_i t_i\right)} \text{ mm}$$

where E_i, t_i and x_i are as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*.

1.13.3 The resultant tensile stress, σ_{ti}, at the extreme outer fibre of an individual ply, i, is to be determined from:

$$\sigma_{ti} = \frac{0,1 E_{ti} y_i M}{\Sigma\left(E_{ti} I_i\right)} \text{ N/mm}^2$$

where σ_{ti}, E_{ti}, y_i, M, E_i and I_i are as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*.

1.13.4 The resultant compressive stress, σ_{ci}, at the extreme outer fibre of an individual ply, i, is to be determined from:

$$\sigma_{ci} = \frac{0,1 E_{ci} y_i M}{\Sigma\left(E_i I_i\right)} \text{ N/mm}^2$$

where σ_{ci}, E_{ci}, y_i, M, E_i and I_i are as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*.

1.13.5 The effective flexural modulus of elasticity in bending, E_{fp}, for the plate laminate is to be determined from:

$$E_{fp} = \frac{\Sigma\left(E_i I_i\right)}{I_p} \text{ N/mm}^2$$

where E_{ti}, I_i and I_P are as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*.

1.13.6 The apparent flexural strength, σ_f, of a plate laminate is to be determined from:

$$\sigma_f = E_{fp} e_f \text{ N/mm}^2$$

where E_{fp} and e_f are as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*.

1.14 Mechanical properties sandwich laminates

1.14.1 For the application of the various formulae relating to the use of sandwich construction, the following assumptions have been made:

(a) the sandwich skins carry the majority of the bending load,

(b) the core carries the majority of the shear load,

(c) the initial estimate of the skin thickness from *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.2* is based upon the limiting condition for thin skin theory:

$$\frac{\text{Core thickness}}{\text{Mean facing thickness}} \geq 5,77$$

(d) the sandwich skins are of approximately equal thickness (i.e. the panel is of balanced or approximately balanced construction), with the thickness of the outer sandwich facing not greater than:

t_{OUTER} = 1,33 t_{INNER} (excluding gel coat and non-structural materials).

1.14.2 An estimate of the thicknesses of the sandwich skins and core required to carry the Rule bending moment may be determined from the following formula. The subsequent design is then to be tested against the other criteria required by the Rules.

$$t_s = \phi_1 k_s b \sqrt[3]{\frac{p}{E_{tps}}} \text{ mm}$$

where

Φ_1 = 0,0214 for inner skins

= 0,0286 for outer skins

where

= 0,1440 for core thickness

k_S, E_{tps}, b and p are as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*.

1.14.3 Where it is proposed to use a thicker core than assumed in *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.2*, the required skin thickness, t_s, is to be calculated from:

$$t_s = \frac{\varphi_2 p\, b^3}{E_{tps} t_c^2} \times 10^{-3} \text{ mm}$$

where

φ_2 = 0,446 for inner skins

= 0,594 for outer skins

k_S, E_{tps}, b and p are as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*.

1.14.4 The tensile modulus, E_{tp}, of a plate laminate which forms a skin of a sandwich laminate subject to tensile loading is to be determined from:

$$E_{tps} = \frac{\Sigma\left(E_{ti} t_i\right)}{\Sigma\, t_i} \text{ N/mm}^2$$

where E_{tps}, E_{ti} and t_i are as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*.

1.14.5 The compressive modulus, E_{cp}, of a plate laminate which forms a skin of a sandwich laminate subject to compressive loading is to be determined from:

$$E_{cps} = \frac{\Sigma\left(E_{ci} t_i\right)}{\Sigma\, t_i} \text{ N/mm}^2$$

where E_{cps}, E_{ci} and t_i are as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*.

1.14.6 The distance of the neutral axis, x_S, from the outer surface of the sandwich laminate is to be determined from:

$$x_s = \frac{\Sigma\left(E_i t_i x_i\right)}{\Sigma\left(E_{ti} t_i\right)} \text{ mm}$$

where E_i, t_i and x_i are as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*.

1.14.7 The resultant tensile stress, σ_{ti}, at the extreme outer fibre of an individual ply, *i*, is to be determined from:

$$\sigma_{ti} = \frac{0,1 E_{ti} y_i M}{\Sigma\left(E_i I_i\right)} \text{ N/mm}^2$$

where σ_{ti}, E_{ti}, y_i, M, E_i and I_i are as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*.

The allowable tensile stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* in Chapter 7, are to be complied with.

1.14.8 The resultant compressive stress, σ_{ci}, at the extreme outer fibre of an individual ply, *i*, is to be determined from:

$$\sigma_{ci} = \frac{0,1 E_{ci} y_i M}{\Sigma\left(E_i I_i\right)} \text{ N/mm}^2$$

where σ_{ci}, E_{ci}, y_i, M, E_i and $\boldsymbol{I}_i$ are as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*.

The allowable compressive stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* in Chapter 7, are to be complied with.

1.14.9 The direct core shear stress, τ_c, at the edges of a sandwich panel subjected to lateral pressure is to be determined from:

$$\tau_c = \frac{p\, b\, k_s}{2\left(t_c + t_s\right)} \times 10^{-3} \text{ N/mm}^2$$

where

k_S = aspect ratio correction factor

= $0{,}32\, A_R + 0{,}36$ for $A_R \leq 2$

= $1{,}0$ for $A_R > 2$

A_R = panel length/panel breadth

t_c and t_s are as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*.

The allowable shear stress limits against core shear failure indicated in *Pt 8, Ch 7, 3.5 Core shear stress 3.5.1* are to be complied with. For the purposes of this comparison it is assumed that the stated shear properties of the proposed core material have been determined by use of the four point sandwich beam bending test ASTM C393 or equivalent.

1.14.10 Where the core shear stress, τ_c, determined from *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.9* is in excess of the limiting stress for a particular core material, the effective shear strength of the core material in the direction of the panel breadth, may be increased by the addition of shear ties. The effective shear strength, τ_{eff}, of the core material is to be determined from:

$$\tau_{eff} = \tau_c + \left(\frac{t_t}{s_t} \times \tau_t\right) \text{ N/mm}^2$$

where

τ_{eff} = effective shear strength of the core material, in N/mm^2

τ_c = shear strength of basic core material, in N/mm^2

t_t = thickness of shear tie material, in mm

τ_t = ultimate shear strength of the shear tie material, in N/mm^2

s_t = spacing or mean spacing of the shear ties, in mm.

1.14.11 Where the Poisson's ratio, υ_f, for a particular facing laminate is known, the deflection, δ, of a flat sandwich panel with all edges assumed to be fully fixed, and subjected to a uniform lateral pressure is to be determined from:

$$\delta = \frac{p\,b^2}{8}\left(\frac{b^2\left(1 - \upsilon_f^{\,2}\right)}{48 D_s} k_{db} + \frac{1}{G t_c} k_{ds}\right) \times 10^{-3} \text{ mm}$$

where

k_{db} = bending deflection aspect ratio factor

= $1{,}5 - \dfrac{1}{A_R}$ with A_R not to be taken greater than 2

k_{ds} = shear deflection aspect ratio factor

= $1{,}2 - \dfrac{0{,}6}{A_R}$ with A_R not to be taken greater than 3

A_R = panel length/panel breadth

D_s = flexural rigidity of the sandwich panel per unit mm width

= $= \dfrac{E_{pi} t_{inner} E_{po}\, t_{outer}}{E_{pi} t_{inner} + E_{po}\, t_{outer}} \left(t_c + t_s\right)^2$ Nmm

E_{pi} is the lesser of E_{tps} or E_{cps} of the inner skin

E_{po} is the lesser of E_{tps} or E_{cps} of the outer skin

ν_f, p, b, t_c, t_s, E_{tps}, E_{cps} and G are as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1* t_{inner} and t_{outer} are as defined in *Pt 8, Ch 3, 1.7 Effective width of attached plating 1.7.1*.

1.14.12 Where the Poisson's ratio, υ_f, for a particular facing laminate is not known, the deflection, δ, of a flat sandwich panel with all edges assumed to be fully fixed, and subjected to a uniform lateral pressure is to be estimated from:

$$\delta = \frac{p\,b^2}{8}\left(\frac{b^2}{48D_s}k_{db} + \frac{1}{Gt_c}k_{ds}\right) \times 10^{-3} \text{ mm}$$

where

δ, *p*, *b*, t_c, and *G* are as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*

D_s, k_{db}, k_{ds} are as defined in *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.11*.

1.14.13 The deflection determined from *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.11* or *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.12*, as appropriate, is not to exceed the limiting deflection for the structural element under consideration, as indicated in *Table 7.2.1 Limiting span/deflection ratio* in Chapter 7.

1.15 Stiffeners general

1.15.1 Unless otherwise specified elsewhere in this Part, the Rule bending moment, M_s, to be applied to all stiffening members subjected to uniform lateral pressure is to be determined from:

$$M_s = \varphi_M s\, l_e^2 p \text{ Nm}$$

where

Φ_M = bending moment coefficient as given in *Table 3.1.10 Shear force, bending moment and deflection coefficients*.

1.15.2 Unless otherwise specified elsewhere in this Part, the Rule shear force, F_s, to be applied to all stiffening members subjected to uniform lateral pressure is to be determined from:

$$F_s = \varphi_s p\, s\, l_e\, N$$

where

Φ_s = shear force coefficient as given in *Table 3.1.10 Shear force, bending moment and deflection coefficients*.

1.15.3 The shear stress, τ_S, in the webs of stiffening members of `top-hat' type section is to be determined from:

$$\tau_s = \frac{F_s}{2t_w\, d_w} \text{ N/mm}^2$$

where

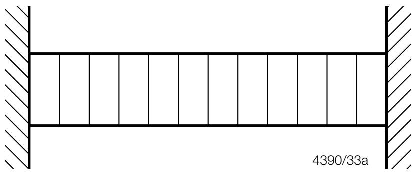
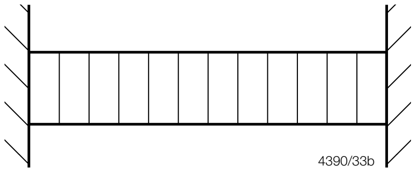
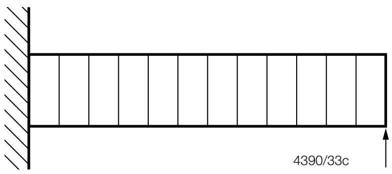
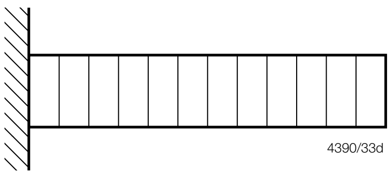
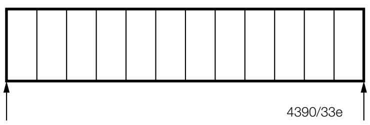
F_s = shear force applied to the stiffening member, in *N*, as detailed in *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.2*

t_w = stiffening member web thickness, in mm

d_w = stiffening member web depth, in mm. (Account is to be taken of the increased effective depth of web where the webs are inclined)

The maximum allowable shear stress is not to exceed that determined from *Table 7.3.1 Limiting stress criteria for local loading* , for the stiffener member under consideration.

Table 3.1.10 Shear force, bending moment and deflection coefficients

Load model	Position (1, 2, 3)	Position	Shear force, Φ_s	Bending moment, Φ_M	Deflection, Φ_δ	Application
(a)		1	1/2	1/12	-	Primary and other members where the end fixity is considered encastre
		2	-	1/24	1/384	
		3	1/2	1/12	-	
(b)		1	1/2	1/10	-	Local, secondary and other members where the end fixity is considered to be partial
		2	-	1/10	1/288	
		3	1/2	1/10	-	
(c)		1	5/8	1/8	-	Various
		2	-	9/128	1/185	
		3	3/8	-	-	
(d)		1	1	1/2	-	Various
		2	-	-	-	
		3	-	-	1/8	
(e)		1	1/2	-	-	Hatch covers, glazing and other members where the ends are simply supported
		2	-	1/8	5/384	
		3	1/2	-	-	

1.15.4 The shear stress, τ_S, in the webs of stiffening members of inverted angle or `T bar' type section is to be determined from:

$$\tau_s = \frac{F_s}{t_w d_w} \text{ N/mm}^2$$

where F_S, t_W and d_W are as defined in *Pt 8, Ch 3, 1.15 Stiffeners general 1.15.3*.

The maximum allowable shear stress is not to exceed that determined from *Table 7.3.1 Limiting stress criteria for local loading* in Chapter 7, for the stiffener member under consideration.

1.15.5 Unless otherwise specified elsewhere in this Part, the deflection, δ_S, of stiffening members, subjected to uniform lateral pressure is to be determined from:

$$\delta_s = \frac{\varphi_\delta \, p \, s \, l_e^4}{(EI)s} \times 10^5 \text{ mm}$$

where

$(E\,I)_S$ = total $E\,I$ for the stiffener section including an effective width of attached plating as indicated in *Pt 8, Ch 3, 1.7 Effective width of attached plating 1.7.1*, in Ncm^4/mm^2

φ_δ = deflection coefficient as defined in *Table 3.1.10 Shear force, bending moment and deflection coefficients*

s, l_e, E, I and p are as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*.

1.15.6 The maximum allowable deflection is not, in general, to exceed that determined from *Table 7.2.1 Limiting span/deflection ratio* for the stiffener member under consideration.

1.16 Geometric properties stiffener sections

1.16.1 The effective geometric properties of the stiffener sections are to be calculated directly from the dimensions of the section and associated effective width of attached plating in accordance with *Pt 8, Ch 3, 1.7 Effective width of attached plating*. Where the mean line of the stiffener webs is not normal to the attached laminate, and the angle exceeds 20°, the properties of the section are to be determined about an axis parallel to the attached plate laminate. Where plywood, solid timber, aluminium alloy, steel or other materials are integrated into a stiffening member, the effectiveness of the material is to be determined in accordance with *Pt 8, Ch 3, 1.21 Plywood 1.21.3*. The stress in the individual material is to be limited to the allowable strain associated with the constituent material.

1.16.2 The distance of the neutral axis, x_S, from the outer surface of the plate laminate is to be determined from:

$$x_s = \frac{\Sigma\left(E_i t_i b_i x_i\right)}{\Sigma\left(E_i t_i b_i\right)} \text{ mm}$$

where E_i, t_i, b_i and x_i are as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*.

1.16.3 The resultant extreme fibre tensile stress for an individual ply, σ_{ti}, is to be determined from:

$$\sigma_{ti} = \frac{0,1 E_{ti} y_i M}{\Sigma\,(EI)_s} \text{ N/mm}^2$$

where σ_{ti}, E_{ti}, y_i, M, E_i and I_i are as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*.

The term $(E\,I)_s$ refers to the whole stiffener section, i.e. including the attached plating in accordance with *Pt 8, Ch 3, 1.7 Effective width of attached plating*. *See also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*.

1.16.4 The resultant extreme fibre compressive stress for an individual ply, σ_{ci}, is to be determined from:

$$\sigma_{ci} = \frac{0,1 E_{ci} y_i M}{\Sigma\,(EI)_s} \text{ N/mm}^2$$

where σ_{ci}, E_{ci}, y_i, M, E_i and I_i are as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*.

The term $(E\,I)_s$ refers to the whole stiffener section, i.e. including the attached plating in accordance with *Pt 8, Ch 3, 1.7 Effective width of attached plating*. *See also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*.

1.17 Stiffener proportions

1.17.1 From structural stability and local buckling considerations, the proportions of stiffening members are, in general, to be in accordance with the requirements of this Section.

1.17.2 The thickness of the web for `top-hat' type stiffeners, t_w, is to be not less than that required to satisfy the web shear from *Pt 8, Ch 3, 1.15 Stiffeners general 1.15.3* and *Pt 8, Ch 3, 1.15 Stiffeners general 1.15.4*, and in no case is to be taken as less than that determined from the following formula:

$$t_w = \frac{0,025\, d_w + 1,1}{1,3\, f_w + 0,61} \text{ mm}$$

where

d_w = unsupported web depth, in mm

f_w = fibre content, by weight, of the web laminate

1.17.3 The thickness of the web of an inverted angle or `T' bar stiffener section is to be twice the web thickness determined from *Pt 8, Ch 3, 1.17 Stiffener proportions 1.17.2*.

1.18 Determination of span points

1.18.1 The effective span, l_e, of a stiffening member is generally less than the overall length, l , by an amount which depends on the design of the end connections. The span points, between which the value of l_e is measured, are to be determined from:

(a) For secondary stiffening members of top-hat type section as shown in *Figure 3.1.3 Span points* the span point is to be taken at the point where the depth of the end bracket, measured from the face of the secondary stiffening member is equal to the depth of the member. Where there is no end bracket, the span point is to be measured between primary member webs.

(b) For primary stiffening members of top-hat type section as shown in *Figure 3.1.4 Span points* the span point is to be taken at the point where the depth of the end bracket, measured from the face of the primary stiffening member is equal to the half depth of the member. Where there is no end bracket, the span point is to be measured between primary member webs.

1.18.2 Where the stiffener member is inclined to a vertical or horizontal axis and the inclination exceeds 10°, the span is to be measured along the member.

1.18.3 Where the stiffening member is curved then the span is to be taken as the effective chord length.

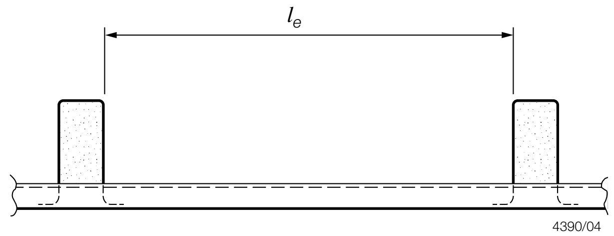


Figure 3.1.3 Span points

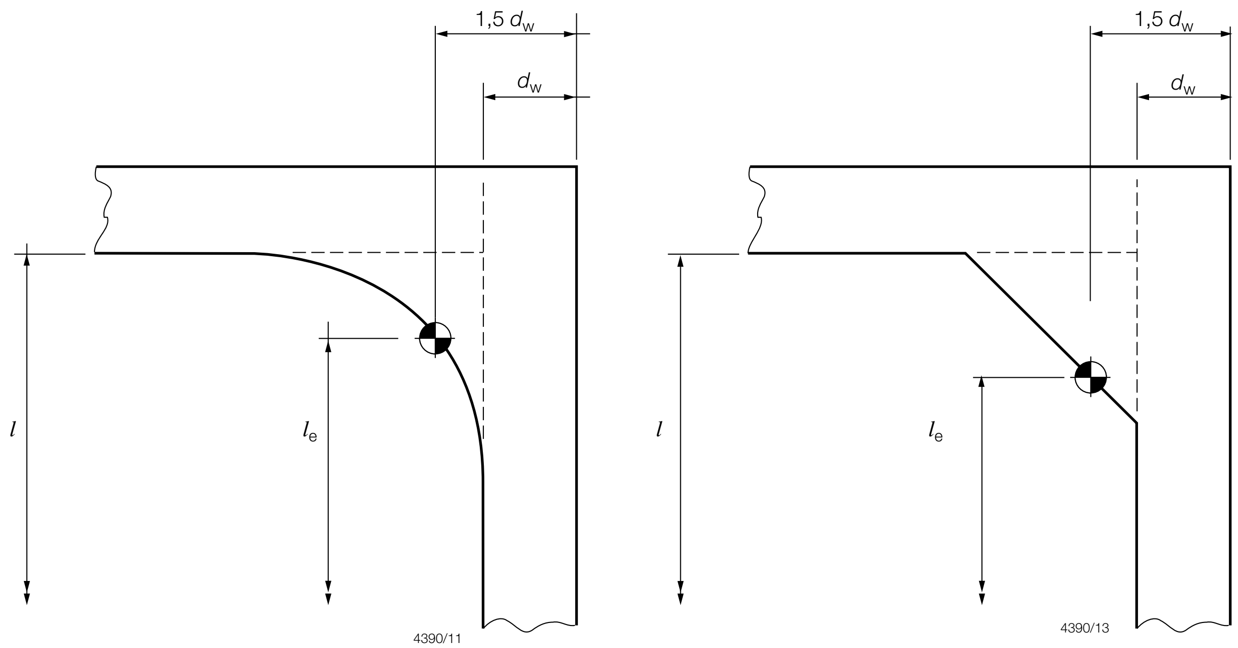


Figure 3.1.4 Span points

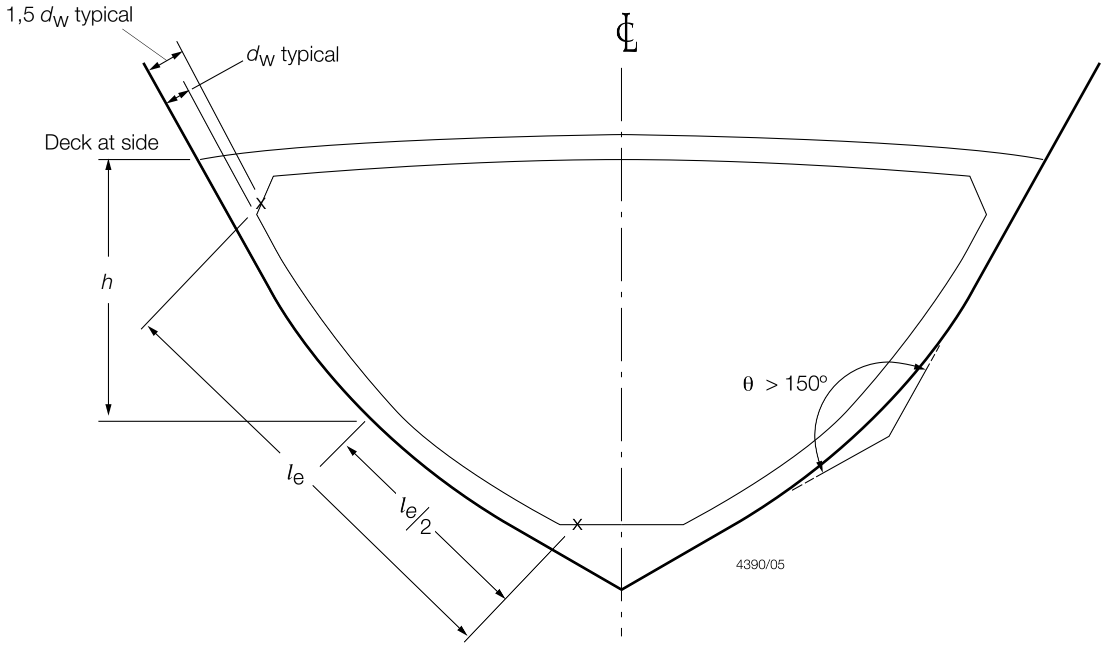


Figure 3.1.5 Span points

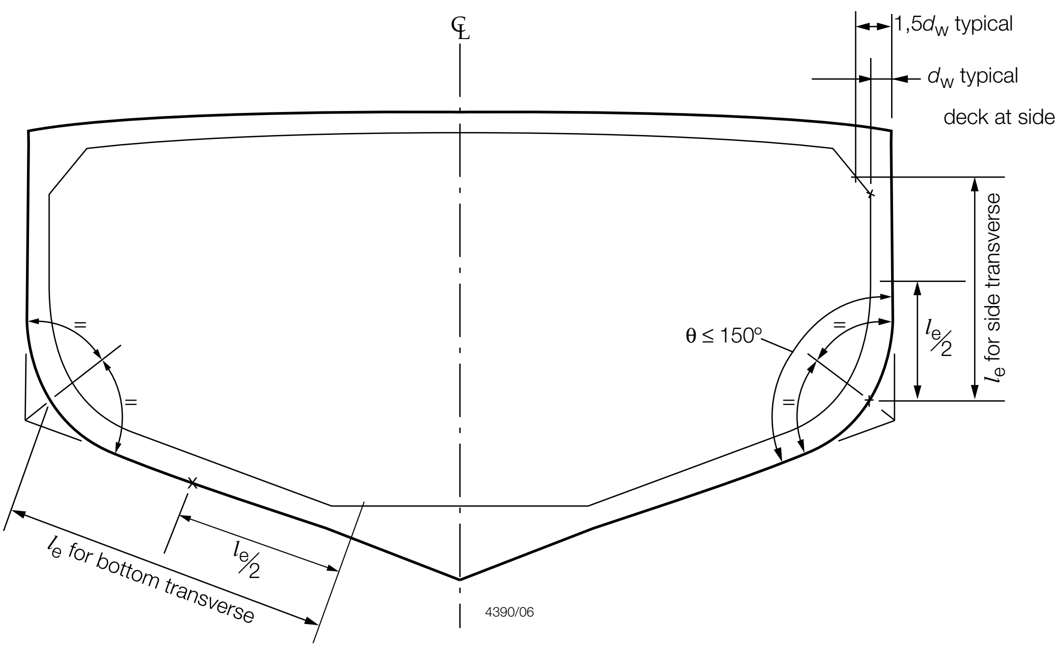


Figure 3.1.6 Span points

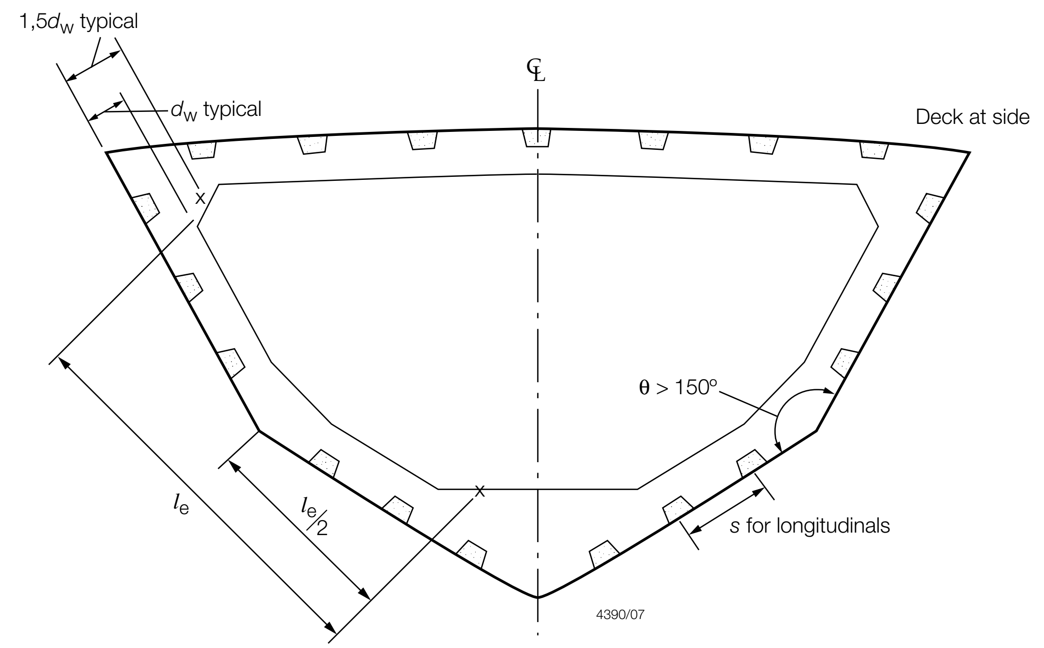


Figure 3.1.7 Span points

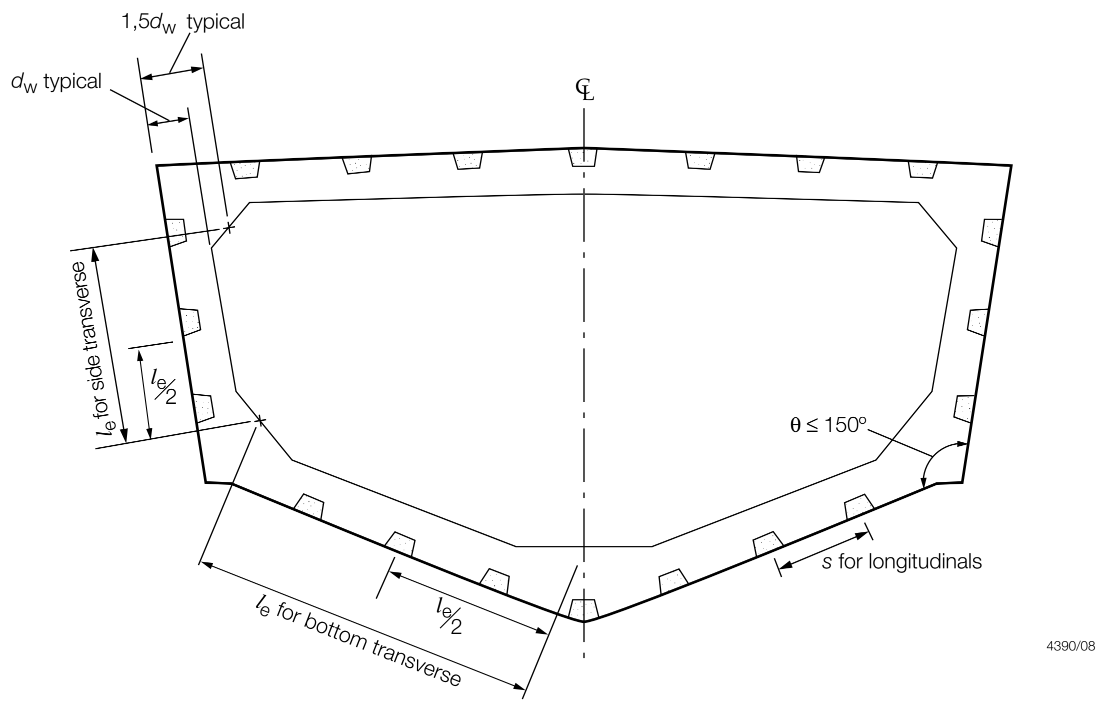


Figure 3.1.8 Span points

1.18.4 Where there is a pronounced turn of bilge, chine or the structure is significantly pitched, the span is to be measured as in *Figure 3.1.5 Span points*, *Figure 3.1.6 Span points*, *Figure 3.1.7 Span points* and *Figure 3.1.8 Span points*.

1.18.5 The determined effective span assumes that the ends of stiffening members are substantially fixed against rotation and displacement. If the arrangement of supporting structure is such that this condition is not achieved, the span is to be determined excluding any effect from the end brackets.

1.19 Boundary bonding

1.19.1 The connection of the various laminates into assemblies and the connection of units to the main structure is generally to be made by means of single or double angles of the type shown in *Figure 3.1.9 Bonding angles*.

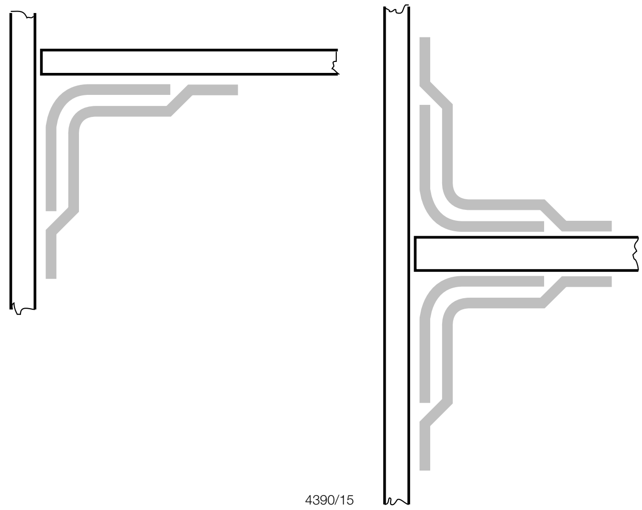


Figure 3.1.9 Bonding angles

1.19.2 These matting-in angles are to be formed by layers of reinforcements, laid-up *in situ*, and normally secondary bonded to the structure before the laminates are advanced in cure. Where the laminating schedule is such that this cannot be achieved then suitable peel plies and secondary bonding techniques, as recommended by the resin manufacturer, *see Pt 8, Ch 2, 5.9 Secondary bonding and peel ply*, are to be arranged in way of the surfaces to be connected.

1.19.3 All surfaces to be bonded are to be clean and suitably prepared prior to the application of the bonding angles. Suitable fillets of compliant resin are to be arranged as shown in *Figure 3.1.10 Resin fillets* and *Figure 3.1.11 Width of bonding angle*.

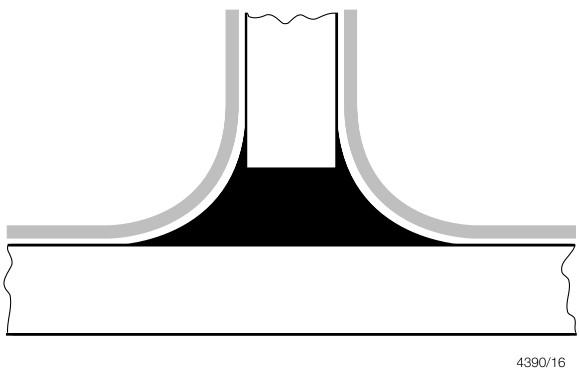


Figure 3.1.10 Resin fillets

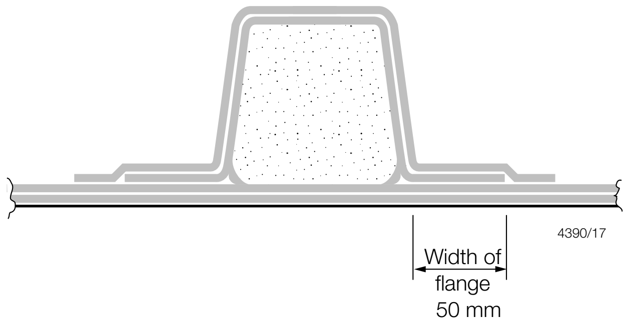


Figure 3.1.11 Width of bonding angle

1.19.4 Where floors, bulkheads, tank boundaries, etc. are manufactured from plate laminate the weight of the laminate forming each angle is to be not less than 50 per cent of the weight of the lighter member being connected, or 900g/m^2 chopped fibre reinforcement or equivalent, whichever is the greater.

1.19.5 Double angles are normally to be used, but when this is not possible, such as where satisfactory access cannot be achieved on the reverse side, a single angle can be used provided it is suitably increased in width and weight. The weight of a single bonding angle is to be determined by direct calculation, and in no case to be taken as less than two thirds the weight of the lighter laminate being connected or 900g/m^2 chopped fibre reinforcement or equivalent, whichever is the greater.

1.19.6 Where frames and stiffeners are of the `top-hat' type, the width of the flange connection to the plate laminate is to be as shown in *Figure 3.1.11 Width of bonding angle*. The width of bonding angle is to be 25 mm for the first layer + 15mm per each additional layer, but not less than 50 mm.

1.19.7 Where sandwich panels are to be connected the weight of bonding is to be not less than the weight of the appropriate skin. The inner and outer skins of primary sandwich structures such as bulkheads are to be effectively `tied' by a suitable weight of reinforcement or by use of fillets and wedges of suitable compliant resin, as shown in *Figure 3.1.12 Bonding ties*.

1.19.8 Where the floors, bulkheads, etc. are manufactured from plywood the weight of the laminate forming each angle is to be not less than 50 per cent of the weight of the equivalent thickness of bulkhead in the material used for the bonding angle or the lighter member being connected.

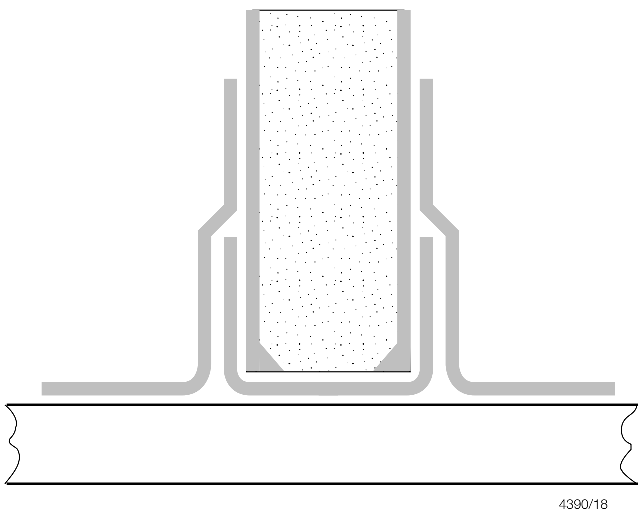


Figure 3.1.12 Bonding ties

1.19.9 In no case is the thickness of the double bonding angle to be less than 2 mm at a glass content, by weight, of 0,5. Where a glass content is less than 0,5, the thickness is to be not less than that required to resist the same shear force using the formulae in *Table 3.1.1 Mechanical properties for chopped strand mat (CSM) glass reinforced polyester resin laminates* and *Table 3.1.2 Mechanical properties for woven roving (WR) and cross-plied (CP) glass reinforced polyester resin laminates at 0/90° degree orientation*.

1.19.10 Alternative bonding arrangements incorporating epoxy fillets, bonded wedges, bolting, etc. may be specially considered. It is however the responsibility of the Builder to demonstrate their suitability and equivalence to the Rule requirements.

1.20 Timber

1.20.1 It is presumed that, in the selection of the species of timber for a particular application, the designers will relate the known characteristics, strength, density, bending and working capabilities of the particular species to the constructional design. The mechanical properties of timbers and assumptions used for design purposes are to be clearly indicated on the submitted construction plans, *see also Pt 8, Ch 2, 2.17 Plywood* and *Pt 8, Ch 2, 1.15 Scaffolding 1.15.1*.

1.20.2 All timbers are to be identified by their botanical name.

1.20.3 The moisture content of timber which is to be glued, bonded or overlaminated is to be about 15 per cent, *see also Pt 8, Ch 2, 2.17 Plywood*.

1.21 Plywood

1.21.1 Structural plywoods are to comply with *Pt 8, Ch 2, 2.17 Plywood*, *see also Pt 8, Ch 2, 2.16 Materials for integrated structural members 2.16.3*.

1.21.2 The mechanical properties of the plywood proposed for use in structural applications is to be obtained from the plywood manufacturer and submitted for consideration. In the absence of such data the mechanical properties can be determined from *Table 3.1.11 Mechanical properties for plywood panels* and *Table 3.1.12 Mechanical properties for plywood on edge*.

Table 3.1.11 Mechanical properties for plywood panels

Mechanical property	N/mm^2
Flexural modulus parallel to face grain, $E_{//}$	$(34{,}1N^2 - 985N + 14800)\,\dfrac{r_{WD}}{1000}$
Flexural modulus perpendicular to face grain, $E_{\perp}$	$(-31{,}5N^2 + 909N - 633)\,\dfrac{r_{WD}}{1000}$
Flexural strength parallel to face grain, $\sigma_{//}$	$(0{,}15N^2 - 4{,}52N + 79{,}5)\,\dfrac{\rho_{WD}}{1000}$
Flexural strength perpendicular to face grain,$\sigma_{\perp}$	$(-0{,}1N^2 + 2{,}88N + 18{,}5)\,\dfrac{\rho_{WD}}{1000}$
Note 1. N is the number of plies and is an odd number between 3 and 15. Note 2. ρ_{WD} is the density of plywood in kg/m^3.	

Table 3.1.12 Mechanical properties for plywood on edge

Mechanical property	N/mm^2
Flexural modulus parallel to face grain, $E_{//}$	$E_{//} = (15{,}6N^2 - 400N + 9850)\,\dfrac{\rho_{WD}}{1000}$
Flexural modulus perpendicular to face grain, $E_{\perp}$	$E_{\perp} = (-15{,}6N^2 + 400N + 3880)\,\dfrac{\rho_{WD}}{1000}$
Flexural modulus at any intermediate angle, E_{θ}	$E_{\theta} = E_{//}\cos^4\theta + 4G_{IP}\cos^2\theta\sin^2\theta + E_{\perp}\sin^4\theta$

Flexural strength parallel to face grain, $\sigma_{//}$	$\sigma_{//} = (0{,}093N^2 - 2{,}4N + 58{,}2)\,\dfrac{\rho_{WD}}{1000}$
Flexural strength perpendicular to face grain, $\sigma_{\perp}$	$\sigma_{\perp} = (-0{,}093N^2 + 2{,}4N + 22{,}4)\,\dfrac{\rho_{WD}}{1000}$
Flexural strength at any intermediate angle, σ_{θ}	$\sigma_{\theta} = \left(\dfrac{\cos^4\theta}{\sigma_{//}^2} + \dfrac{\cos^2\theta\sin^2\theta}{\sigma_{//}^2\tau^2}\left(\sigma_{//}^2 - \tau^2\right) + \dfrac{\sin^4\theta}{\sigma_{\perp}^2}\right)^{-1/2}$
In-plane shear modulus parallel/perpendicular to face grain, G_{IP}	$G_{IP} = 0{,}9\rho_{WD}$
In-plane shear modulus at any intermediate angle, G_{θ}	$G_{\theta} = (E_{//} + E_{\perp} - 2G_{IP})\cos^2\theta\sin^2\theta + G_{IP}(\cos^4\theta + \sin^4\theta)$
In-plane shear strength parallel/perpendicular to face grain, τ_{IP}	$\tau_{IP} = 0{,}015\rho_{WD}$
In-plane shear strength at any intermediate angle, τ_{θ}	$\tau_{\theta} = \left[\cos^2\theta\sin^2\theta\left(\dfrac{8}{\sigma_{//}^2} + \dfrac{4}{\sigma_{\perp}^2}\right) + \dfrac{\left(\cos^2\theta - \sin^2\theta\right)^2}{\tau_{IP}^2}\right]^{-1/2}$
Note 1. N is the number of plies and is an odd number between 3 and 15. **Note** 2. ρ_{WD} is the density of plywood in kg/m^3.	

1.21.3 Where stiffeners incorporate encapsulated plywood structurally bonded to the plate laminate in accordance with *Pt 8, Ch 3, 1.19 Boundary bonding 1.19.8*, its effective $E_i I_i$ is to be incorporated into the $\Sigma(E_i I_i)$ as indicated in *Pt 8, Ch 3, 1.16 Geometric properties stiffener sections*, with the basic thickness and tensile/compressive moduli of the plywood being taken as those corresponding to the least effective over the span of the stiffener. Directional considerations for structural plywood incorporated in stiffening members are to be indicated on construction plans submitted for appraisal.

1.22 Aluminium alloy

1.22.1 The use of aluminium alloy is permitted for craft in accordance with *Pt 7 Hull Construction in Aluminium*. Where this material is to be integrated structurally, with the fibre composite structure, *see Pt 8, Ch 2, 2.15 Adhesives* and *Pt 8, Ch 2, 1.15 Scaffolding 1.15.1*.

1.23 Steel

1.23.1 The use of steel is permitted for craft in accordance with *Pt 6 Hull Construction in Steel*. Where this material is to be integrated structurally, with the fibre composite structure, *see Pt 8, Ch 2, 2.15 Adhesives* and *Pt 8, Ch 2, 1.15 Scaffolding 1.15.1*.

1.24 Other materials

1.24.1 Special consideration will be given to the use of other types of materials. Details of the type of material, the specification to which it was manufactured and its mechanical properties are to be submitted for appraisal, *see also Pt 8, Ch 3, 1.16 Geometric properties stiffener sections 1.16.1*.

1.25 Secondary member end connections

1.25.1 Secondary members, i.e. longitudinals, beams, frames and bulkhead stiffeners forming part of the hull structure are, in general, to be connected at their ends in accordance with the requirements of this Section. Where it is desired to adopt bracketless connections, the proposed arrangements will be individually considered on the basis of *Pt 8, Ch 3, 1.18 Determination of span points 1.18.5*.

1.25.2 Where end connections are fitted in accordance with these requirements, they may be taken into account in determining the effective span of the member.

1.25.3 Where a longitudinal strength member is cut at a primary support and the continuity of strength is provided by brackets, the scantlings of the brackets are to be such that their section properties and effective cross-sectional area are not less than those of the member. Care is to be taken to ensure correct alignment of the brackets on each side of the primary member.

1.25.4 The thickness of the bracket webs is to be not less than that required for the webs of the stiffening member. *See Pt 8, Ch 3, 1.15 Stiffeners general*.

1.25.5 The arrangement of the connection between the stiffener and the bracket is to be such that at no point in the connection are the properties reduced to less than that of the stiffener with associated plating.

1.25.6 The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint.

1.25.7 Hard spots are to be avoided in way of end connections.

1.26 Scantlings of end brackets

1.26.1 Secondary members, i.e. longitudinals, beams, frames and bulkhead stiffeners forming part of the hull structure, are generally to be connected at their ends in accordance with the requirements of this Section. Where it is desired to adopt bracketless connections, the proposed arrangements will be individually considered.

1.26.2 Where end connections are fitted in accordance with these requirements, they may be taken into account in determining the effective span of the member.

1.26.3 The symbols used in this sub-Section are defined as follows:

t_w = the thickness of the bracket web, in mm

$E I$ = section stiffness of the secondary member, in Ncm^4/mm^2

1.26.4 Typical arrangements of stiffener end brackets are shown diagrammatically in *Figure 3.1.13 Arrangement of end brackets*.

1.26.5 The section stiffness, (EI), in way of the bracket at the point to which the effective span of the stiffener, l_e, is measured is to be not less than two times the section stiffness of the basic stiffener.

1.26.6 The web thickness, t_w, and face width of end brackets are to be not less than that of the connecting stiffeners. Additionally the requirements of *Pt 8, Ch 3, 1.17 Stiffener proportions* are to be complied with.

1.26.7 Where brackets are of the inverted angle or `T' bar stiffener section, their free edge is to be suitably stiffened by a flange or other equivalent means. The dimensions of the flange are to be such that the requirements of *Pt 8, Ch 3, 1.17 Stiffener proportions* are complied with.

1.26.8 Where the free edge of the bracket is hollowed out to form a `soft-toe', the dimensions of the bracket arms and throat depth are to be increased such that the stiffness requirements of *Pt 8, Ch 3, 1.17 Stiffener proportions* are complied with.

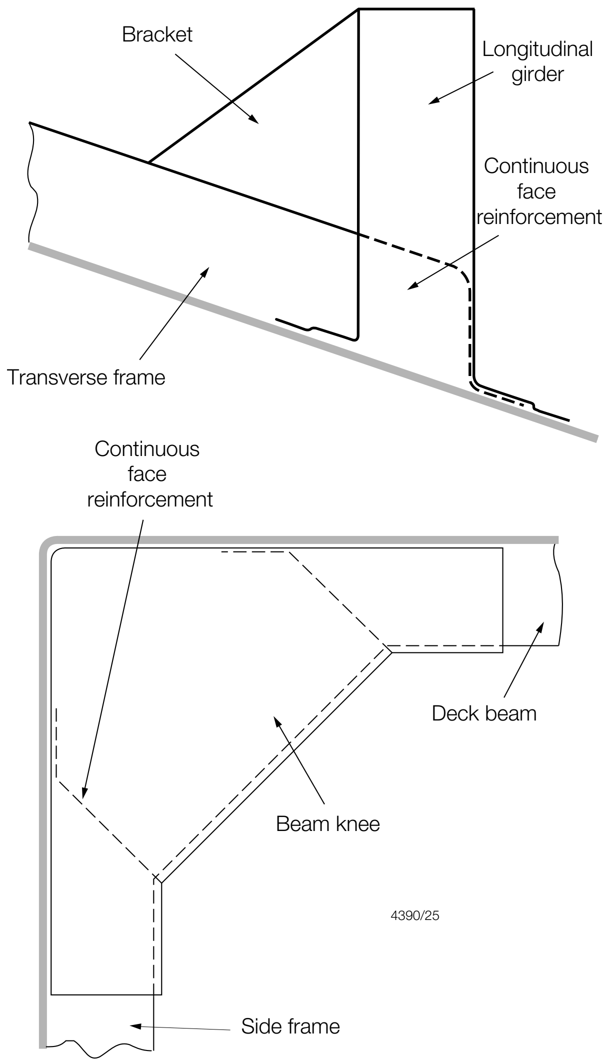


Figure 3.1.13 Arrangement of end brackets

1.27 Primary member end connections

1.27.1 Primary members are to be so arranged as to ensure effective continuity of strength, and abrupt changes of depth or section are to be avoided. Where members abut on both sides of a bulkhead, or on other members, arrangements are to be made to ensure that they are in alignment. Primary members in tanks are to form a continuous line of support and wherever possible, a complete ring system.

1.27.2 The members are to have adequate lateral stability and web stiffening and the structure is to be so arranged as to minimize hard spots and other sources of stress concentration.

1.27.3 Primary members are to be provided with adequate end fixity by end brackets or equivalent structure. The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint and effective distribution of the load from the member.

1.27.4 Where the primary member is supported by structure which provides only a low degree of restraint against rotation, the member is generally to be extended for at least two frame spaces, or equivalent, beyond the point of support before being tapered.

1.27.5 Where primary members are subject to concentrated loads, particularly if these are out of line with the member web, additional strengthening will, in general, be required.

1.27.6 The thicknesses of the bracket webs are, in general, to be not less than those of the primary member webs. Where brackets are of the plate type, the free edge of the bracket is to be adequately stiffened and the plate positioned to limit any hard spot.

1.27.7 Where a deck girder or transverse is connected to a vertical member on the shell or bulkhead, the scantlings of the latter may be required to be increased to provide adequate stiffness to resist rotation of the joint.

1.27.8 Where a member is continued over a point of support, such as a pillar or pillar bulkhead stiffener, the design of the end connection is to be such as to ensure the effective distribution of the load into the support. Proposals to fit brackets of reduced scantlings, or alternative arrangements, will be considered.

1.27.9 Connections between primary members forming a ring system are to minimize stress concentrations at the junctions. Integral brackets are generally to be radiused or well rounded at their toes. The arm length of the bracket, measured from the face of the member, is to be not less than the depth of the smaller member forming the connection.

1.28 Arrangements and details

1.28.1 The arrangement of the connection between the stiffener and the bracket is to be such that at no point in the connection is the section stiffness ($E\,I$), reduced to less than that of the stiffener with associated plating.

1.28.2 The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint.

1.29 Web stability

1.29.1 The stability of composite beams, girders, stringers etc. is to be analysed with respect to global buckling due to compressive loads. The flanges and webs shall be analysed with respect to local buckling due to compressive and shear loads. Design calculations are to be submitted indicating the margin against failure.

1.30 Openings in the webs of stiffening members

1.30.1 Where openings are cut in the webs of stiffening members, the depth of the opening is not to exceed 50 per cent of the web depth, and the opening is to be so located that the edges are not less than 25 per cent of the web depth from the face laminate. The length of opening is not to exceed the web depth or 60 per cent of the secondary member spacing, whichever is the greater, and the ends of the openings are to be equidistant from the corners of cut-outs for secondary members. Where larger openings are proposed, the arrangements and compensation required will be specially considered.

1.30.2 Openings are to have smooth edges and well rounded corners. Exposed edges in way of cut-outs in single skin/plate laminate are to be suitably sealed with resin and/or be over laminated. Exposed edges in way of cut-outs in sandwich panels and top hat type stiffening members are to be overlaminated with a weight of laminate not less than the lower of the two skins which form the panel (or stiffener) or 2 mm in thickness whichever is the greater.

1.30.3 Cut-outs for the passage of secondary members are to be arranged so as to minimise the creation of stress concentrations. To avoid excessive use of filler material the breadth of cut-out is to be kept as small as necessary and the fit as accurate as practicable. Suitable fillets are to be arranged to ensure efficient bonding.

1.30.4 Consideration is to be given to the provision of adequate drainage and unimpeded flow of air and water when designing the cut-outs and connection details.

1.31 Continuity and alignment

1.31.1 The arrangement of material is to be such as will ensure structural continuity. Abrupt changes of shape or section, sharp corners and points of stress concentration are to be avoided.

1.31.2 Where members abut on both sides of a bulkhead or similar structure, care is to be taken to ensure good alignment.

1.31.3 Pillars and pillar bulkheads are to be fitted in the same vertical line wherever possible, and elsewhere arrangements are to be made to transmit the out of line forces satisfactorily. The load at head and heel of pillars is to be effectively distributed and arrangements are to be made to ensure the adequacy and lateral stability of the supporting members.

1.31.4 Continuity is to be maintained where primary members intersect and where the members are of the same depth, *see also* LR's *Guidance Notes for Structural Details*.

1.31.5 End connections of structural members are to provide adequate end fixity and effective distribution of the load into the supporting structure.

1.31.6 The toes of brackets, etc. are not to land on unstiffened panels of plating. Special care is to be taken to avoid notch effects at the toes of brackets, by making the toe concave or otherwise tapering it off in accordance with *Figure 3.4.1 `Soft-toe'* in Chapter 3.

1.32 Arrangements at intersection of continuous secondary and primary members

1.32.1 Cut-outs for the passage of secondary members through the webs of primary members, and the related bonding arrangements, are to be so designed as to minimize stress concentrations around the perimeter of the opening and in the attached hull envelope or bulkhead plating. The critical shear buckling stress of the panel in which the cut-out is made is to be examined. Longitudinals will be required to have double bonding angles which may require to be locally increased in weight in areas of high stress, such as under bulkheads, machinery seating, mast steps, etc. The increased shear stresses in these areas are to be examined.

1.32.2 It is recommended that the web plate connection to the hull envelope, or bulkhead end in a smooth tapered `soft toe'. Recommended shapes of cut-out are shown in Chapter 3, *Figure 3.4.1 `Soft-toe'*, but consideration will be given to other shapes on the basis of maintaining equivalent strength and minimising stress concentration.

1.32.3 Alternative arrangements will be considered on the basis of their ability to transmit load with equivalent effectiveness. Details of the calculations made and testing procedures are to be submitted.

■ *Section 2*
Minimum thickness requirements

2.1 General

2.1.1 Structural laminates, used for both single skin and sandwich construction are, in general, to incorporate not less than 40 per cent, by weight, of woven or cross-ply reinforcement.

2.2 Single skin laminate

2.2.1 The minimum thicknesses of single skin laminates are as indicated in the appropriate Sections.

2.3 Sandwich skin laminate

2.3.1 The minimum amount of reinforcement in single skin laminates which form the inner and outer skins of sandwich panels are as indicated in *Pt 8, Ch 3, 2.5 Minimum skin reinforcement in sandwich laminates 2.5.1*. Where the structural requirements for thickness of either the bottom shell outer skin, or inner skin in way of an integral tank, is less than that required by *Pt 8, Ch 3, 2.5 Minimum skin reinforcement in sandwich laminates 2.5.1*, a 20 per cent reduction in the minimum amount of reinforcement will be acceptable, conditional upon a vacuum test to demonstrate the watertight integrity and also an impact test for impact resistance of the laminate, *see Pt 8, Ch 3, 2.9 Sheathing 2.9.2*.

2.4 Laminate thickness of single skin laminates

2.4.1 The Rule minimum skin thicknesses for single skin laminates as determined from the appropriate Sections of the Rules are to be corrected for craft type irrespective of the reinforcement being used, the corrected minimum skin thickness of side, bottom, transom, wet-deck, vehicle deck and weather decks is to be determined from:

Single skin laminates:

$$t_{\mathrm{T}} = \omega\, t_{\mathrm{min}}$$

where

ω = Service Type Correction Factor given in *Table 3.2.1 Service type correction factor (ω)*

t_{T} = Rule minimum thickness corrected for craft type, in mm

t_{min} = Rule basic minimum laminate thickness, in mm.

Table 3.2.1 Service type correction factor (ω)

Service type notation	ω
Cargo	1,1
Passenger	1,00
Patrol	1,00
Pilot	1,1
Yacht	1,00
Workboat - Motor fishing vessel	1,2

2.4.2 All minimum thicknesses of laminate for both stiffener and single skin laminate components are based on an assumed fibre content, f_c, of 0,5. Where the fibre content by weight, f_c, is less than 0,5 the required minimum thicknesses are to be determined from:

$$t_{fc} = t_{0,5}\left(1,65 - 1,3f_c\right) \text{ mm}$$

where

t_{fc} = minimum thickness at actual laminate fibre content, in mm

$t_{0,5}$ = Rule basic minimum laminate thickness at fibre content, by weight, of 0,5

2.4.3 The equation in *Pt 8, Ch 3, 2.4 Laminate thickness of single skin laminates 2.4.2* relates to polyester 'E' glass laminates. Other laminates will be considered on an equivalence basis.

2.5 Minimum skin reinforcement in sandwich laminates

2.5.1 The minimum amount of reinforcement in single skin laminates, which form the inner and outer skins of sandwich laminates, is given in *Table 3.2.2 Minimum amount of reinforcement in sandwich laminate skins based on an assumed fibre content, f_c, of 0,5*. The corrected minimum amount of reinforcement, W_T, is to be determined from:

$$W_T = \omega K_L K_V W_{min}$$

where

ω = Service Type Correction Factor, *see Pt 8, Ch 3, 2.5 Minimum skin reinforcement in sandwich laminates 2.5.2*

K_L = Craft Length Correction Factor, *see Pt 8, Ch 3, 2.5 Minimum skin reinforcement in sandwich laminates 2.5.3*

K_V = Fibre Volume Correction Factor, *see Pt 8, Ch 3, 2.5 Minimum skin reinforcement in sandwich laminates 2.5.4*

Table 3.2.2 Minimum amount of reinforcement in sandwich laminate skins based on an assumed fibre content, f_c, of 0,5

Panel location	Minimum amount of reinforcement, W_{min} (g/m^2)		Sandwich skin length factor, f_{LS}
	Glass	Carbon/Aramid	
Integral tanks, fluid barrier skin	3650	2700	0,0
Hull bottom, outer skin	3650	2700	0,33
Hull bottom, inner skin	2850	2100	0,33
Side shell, outer skin	3250	2400	0,33
Side shell, inner skin	2450	1950	0,33
Inner bottom, outer skin	3650	2700	0,33
Inner bottom, inner skin	2850	2100	0,33

Double bottom plate floor	1650	1300	0,0
Watertight bulkhead	1650	1300	0,0
Deep tanks, exterior skin	2450	1950	0,0
Deep tanks, fluid barrier skin	3250	2400	0,0
Strength/weather deck, outer skin	2450	1950	0,33
Strength/weather deck, inner skin	1650	1300	0,0
Lower deck/within deckhouse, accommodation decks	1650	1300	0,0
Cargo deck, outer skin	2450	1950	0,0
Cargo deck, inner skin	1650	1300	0,0
Superstructure sides	1650	1300	0,0
Superstructure front	2050	1500	0,0
Superstructure aft	1650	1300	0,0
Superstructure top	1650	1300	0,0
Coach roof	1650	1300	0,0
Machinery casings	2050	1500	0,0
Bulwarks	1650	1300	0,0
Note The minimum amount of reinforcement in hybrid laminates will be individually considered on an equivalence basis. *See Pt 8, Ch 3, 2.9 Sheathing 2.9.2*.			

2.5.2 The Rule minimum amount of reinforcement in *Pt 8, Ch 3, 2.5 Minimum skin reinforcement in sandwich laminates 2.5.1* is to be corrected for craft type, irrespective of the reinforcement being used; the service type correction factor for the minimum amount of reinforcement in the side, bottom, transom, wet-deck, vehicle deck and weather decks is to be determined from:

ω = Service Type Correction Factor given in *Table 3.2.1 Service type correction factor (ω)*.

2.5.3 The Rule minimum amount of reinforcement in *Pt 8, Ch 3, 2.5 Minimum skin reinforcement in sandwich laminates 2.5.1* is to be corrected for craft length, irrespective of the reinforcement being used; the craft length correction factor is to be determined from:

K_L = craft length correction factor

= $1{,}0 - f_{LS}$ for $L_R \leq 15$ m

= 1,0 for $L_R \geq 35$ m

Intermediate values of K_L are to be determined by linear interpolation

f_{LS} = sandwich skin length factor given in *Table 3.2.2 Minimum amount of reinforcement in sandwich laminate skins based on an assumed fibre content, f_c, of 0,5* for mono-hull craft and *Table 4.2.1 Minimum amount of reinforcement in sandwich laminate skins* in Chapter 4 for multi-hull craft

= 0,0 for all sandwich panels in cargo, pilot and workboat crafts

L_R = Rule length, in metres, as defined in *Pt 3, Ch 1, 6.2 Principal particulars*.

2.5.4 The minimum amount of reinforcement is based on an assumed fibre content, f_c, of 0,5. Where the fibre content by weight, f_c, is greater than 0,5, the fibre volume correction factor is to be determined from:

K_V = fibre volume correction factor for laminates with fibre content, by weight, greater than 0,5

$$= \left(\frac{1 + \frac{\zeta_F}{\zeta_R}}{1 + \left(\frac{\zeta_F}{\zeta_R}\right)\left(\frac{1 - f_c}{f_c}\right)} \right)^{0,67}$$

= f_c, ζ_F and ζ_R are as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*.

2.5.5 In areas where impact loads are not likely to occur, special consideration will be given to laminates with amount of reinforcement less than that required by *Pt 8, Ch 3, 2.5 Minimum skin reinforcement in sandwich laminates 2.5.1*, provided that all of the structural strength requirements of the Rules are complied with.

2.6 Integral tank structure

2.6.1 The minimum thickness of laminate for all stiffening members passing through, or forming the boundary of integral fuel oil and water tanks is to be not less than 4,5 mm irrespective of fibre content.

2.6.2 Where the boundaries of integral fuel oil and water tanks are of sandwich skin construction the minimum amount of reinforcement in the laminate providing the fluid barrier, without satisfactory material testing, is to comply with the requirements of *Pt 8, Ch 3, 2.5 Minimum skin reinforcement in sandwich laminates 2.5.1*, *see Pt 8, Ch 3, 2.3 Sandwich skin laminate 2.3.1*.

2.6.3 Where the boundaries of integral fuel oil and water tanks are of single skin construction, in no case is the tank laminate thickness, determined in accordance with *Pt 8, Ch 3, 7.4 Deep tanks*, to be less than 5,0 mm irrespective of fibre content.

2.7 Novel features

2.7.1 Where the Rules do not specifically define the requirements for novel features, the scantlings and arrangements are to be determined by direct calculations. Such calculations are to be carried out on the basis of the Rules, Recognised Standards and good practice, and are to be submitted with the relevant construction plans for appraisal, *see also Pt 8, Ch 1, 2.6 Novel features*.

2.8 Impact considerations

2.8.1 Due consideration is to be given to the scantlings of all structures which may be subject to local impact loadings. Impact tests may be required to be carried out at the discretion of LR to demonstrate the suitability of the proposed scantlings for a particular application.

2.8.2 The minimum skin thickness requirements may, subject to the agreement of LR, be reduced provided that suitable impact tests are carried out to demonstrate that the proposed laminates have not less than the equivalent impact resistance to that of a laminate which satisfies the Rule minimum thickness. In addition it is assumed that this reduced laminate satisfies the structural strength and deflection requirements of the Rules.

2.9 Sheathing

2.9.1 Areas of shell and deck which are subject to additional wear by abrasion e.g. passenger routes, working areas of fishing craft, forefoot region, etc, are to be suitably protected by local reinforcement as given in *Pt 8, Ch 3, 3.14 Local reinforcement* or sheathing. This sheathing may be of timber, rubber, steel, additional layers of reinforcement, etc. as appropriate. Details of such sheathing and the method of attachment are to be indicated on the relevant construction plans submitted for appraisal.

2.9.2 The attachment of sheathing by mechanical means such as bolting or other methods is not to impair the structural integrity of the laminate or the watertight integrity of the craft. Through bolting of the hull is to be kept to a minimum and avoided where practicable. The design arrangements in way of any through bolting is to be such that damage to the sheathing will not impair the watertight integrity of the attachment to the hull.

Section 3
Shell envelope laminate

3.1 General

3.1.1 The requirements in respect of the general plating elements of the shell envelope, excluding the deck, are contained within this Section.

3.2 Keel plate

3.2.1 The width, b_K, and thickness, t_K, of plate keels are not to be taken as less than:

$$b_k = 7{,}0L_R + 340 \text{ mm}$$

$$t_K = \sqrt{k_t}\left(5{,}0L^{0{,}45}{}_R\right) \text{ mm}$$

where

$k_t = \dfrac{152}{\sigma_f}$

L_R = Rule length, in metres, as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*

σ_f = ultimate flexural strength of the keel plate material, in N/mm^2, *see Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.6*

3.2.2 In no case is the thickness of the keel to be less than that of the adjacent bottom shell plating.

3.2.3 The width and thickness of plate keels are to be maintained throughout the length of the craft from the transom to a point not less than 25 per cent of the freeboard measured at the forward perpendicular (FP), above the deepest load waterline on the stem. Thereafter the keel thickness may be reduced to that required by *Pt 8, Ch 3, 3.3 Stem plate* for the stem. Laminate tapers are to be in accordance with *Pt 8, Ch 2, 3.9 Laminate detail*.

3.2.4 Where the bottom shell is of sandwich construction the keel is, in general, to be formed by locally returning to single skin construction for a width as required by *Pt 8, Ch 3, 3.2 Keel plate 3.2.1*. The Rule thickness of keel is to comprise both the inner and outer skins of the adjacent bottom shell sandwich plus additional reinforcement as required. The distribution of reinforcement in way of the plate keel and sandwich bottom structure is to be in accordance with *Figure 3.3.1 Single skin/sandwich skin intersection detail*.

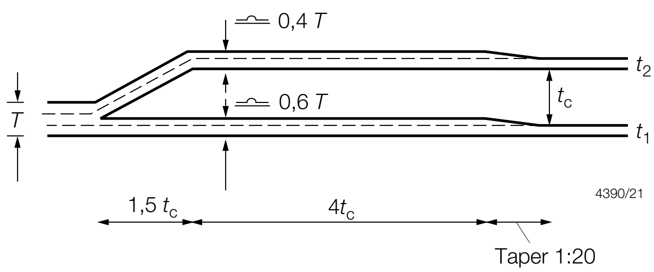


Figure 3.3.1 Single skin/sandwich skin intersection detail

3.2.5 For large or novel craft, or yachts with externally attached ballast keels, or where it is proposed to incorporate keels of the `bar' type the scantlings of the keel will be specially considered.

3.3 Stem plate

3.3.1 The thickness of the plate stem, t_s, is not to be taken as less than that given by the following expression:

$$t_s = \sqrt{k_t}\left(0,29L_R + 9\right) \text{ mm}$$

where

k_t = as defined in *Pt 8, Ch 3, 3.2 Keel plate 3.2.1*

L_R = Rule length, in metres, as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*

σ_f = ultimate flexural strength of the stem plate material, in N/mm^2, *see Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.6*.

3.3.2 In no case is the thickness of the plate stem to be taken as less than the thickness of the adjacent side shell plating.

3.3.3 The width of the plate stem is to be not less than the width of keel as required by *Pt 8, Ch 3, 3.2 Keel plate 3.2.1*.

3.3.4 Plate stems are to be supported by horizontal diaphragms and, where the stem radius is large, a centreline stiffener or web may be required.

3.3.5 Where the side shell is of sandwich construction the stem is to be formed by locally returning to single skin construction for a width as required by *Pt 8, Ch 3, 3.2 Keel plate 3.2.1*. The Rule thickness of stem is to comprise both the inner and outer skins of the adjacent side shell sandwich plus additional reinforcement as required. The distribution of reinforcement in way of the plate stem and sandwich bottom structure is to be in accordance with *Figure 3.3.1 Single skin/sandwich skin intersection detail*.

3.3.6 For large or novel craft, the scantlings of the stem will be specially considered, *see also Pt 8, Ch 3, 5.11 Forefoot and stem*.

3.4 Bottom

3.4.1 The bending moment assumed to be carried by the bottom shell plating is to be not less than that determined from *Pt 8, Ch 3, 1.9 Plate and sandwich laminates 1.9.1*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for high speed or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by *Pt 8, Ch 3, 3.4 Bottom 3.4.2* and *Pt 8, Ch 3, 3.4 Bottom 3.4.4* respectively.

3.4.2 An estimate of the thickness of **bottom single skin plating** is to be determined from *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.1*. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.3* and *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.4*, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* are to be complied with.

3.4.3 In no case is the minimum thickness of single skin plating to be taken as less than 5,5 mm.

3.4.4 An estimate of the stiffness $E\,I$ thickness of single skin plating for outer and inner skins of the **bottom sandwich panel** and the thickness of core material is to be determined from *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.2* and *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.9* respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.7* and *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.8*. The allowable tensile and compressive stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* are to be complied with.

3.4.5 The amount of reinforcement in laminates which form the skins of a sandwich laminate is to comply with the requirements of *Pt 8, Ch 3, 2.5 Minimum skin reinforcement in sandwich laminates 2.5.1*, *see Pt 8, Ch 3, 2.3 Sandwich skin laminate 2.3.1*.

3.4.6 For all craft types, the minimum bottom shell thickness as required by *Pt 8, Ch 3, 3.4 Bottom 3.4.3* and *Pt 8, Ch 3, 3.4 Bottom 3.4.5* is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

3.4.7 Additionally, for high speed craft, the minimum thickness requirements for the bottom shell between the bilge tangential points or chines and the chine line or 150 mm above the static load waterline, whichever is the greater, is not to be less than determined for the side shell using the side shell impact pressure or the bottom shell hydrostatic or pitching pressures associated with a displacement or semi-displacement type craft whichever is the greater, *see Figure 3.3.2 Extent of bottom shell*.

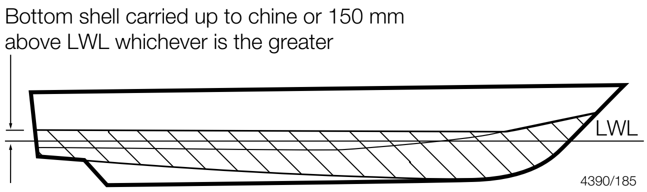


Figure 3.3.2 Extent of bottom shell

3.4.8 Special consideration may be given to laminate thicknesses lesser than those required by *Pt 8, Ch 3, 3.4 Bottom 3.4.2* and *Pt 8, Ch 3, 3.4 Bottom 3.4.4*, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see Pt 8, Ch 3, 2.3 Sandwich skin laminate 2.3.1*, and the equivalent impact resistance is demonstrated as required by *Pt 8, Ch 3, 2.8 Impact considerations 2.8.2*.

3.5 Side

3.5.1 The bending moment assumed to be carried by the side shell plating is to be not less than that determined from *Pt 8, Ch 3, 1.9 Plate and sandwich laminates 1.9.1*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by *Pt 8, Ch 3, 3.5 Side 3.5.2* and *Pt 8, Ch 3, 3.5 Side 3.5.4* respectively.

3.5.2 An estimate of the thickness of **side single skin plating** is to be determined from *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.1*. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.3* and *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.4*. The allowable tensile and compressive stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* are to be complied with.

3.5.3 In no case is the minimum thickness of single skin plating to be taken as less than 5 mm.

3.5.4 An estimate of the stiffness $E\ I$, thickness of single skin plating for outer and inner skins of the **side sandwich panel** and the thickness of core material is to be determined from *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.2* and *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.9* respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.7* and *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.8*. The allowable tensile and compressive stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* are to be complied with.

3.5.5 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of *Pt 8, Ch 3, 2.5 Minimum skin reinforcement in sandwich laminates 2.5.1*.

3.5.6 Special consideration may be given to laminate thicknesses lesser than that required by *Pt 8, Ch 3, 3.5 Side 3.5.3* and *Pt 8, Ch 3, 3.5 Side 3.5.5*, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see Pt 8, Ch 3, 2.3 Sandwich skin laminate 2.3.1*, and the equivalent impact resistance is demonstrated as required by *Pt 8, Ch 3, 2.8 Impact considerations 2.8.2*.

3.6 Sheerstrake

3.6.1 The sheerstrake, is in general, to be taken as the side shell, locally reinforced in way of deck/hull connection and fender attachment. The amount of local reinforcement will be dependent upon the arrangement of structure and the proposed service, but is not to be less than that required by *Pt 8, Ch 3, 3.14 Local reinforcement*.

3.6.2 The fendering arrangements for all craft types are the responsibility of the designers/Builders and are outside the scope of classification.

3.6.3 Where the pressure or impact loadings that a particular type of craft will experience in service are considered by the Builder, or subsequent Owner, to be not covered by, or be greater than, those indicated in *Pt 5 Design and Load Criteria* of the Rules, details of the loadings together with the calculations of how these will be satisfactorily distributed into the craft's structure, are to be submitted for consideration with the relevant contruction plans.

3.6.4 The arrangements indicated in *Pt 8, Ch 3, 3.6 Sheerstrake 3.6.5*, *Pt 8, Ch 3, 3.6 Sheerstrake 3.6.6*, *Pt 8, Ch 3, 4.19 Fenders and reinforcement in way 4.19.5* and *Pt 8, Ch 3, 4.19 Fenders and reinforcement in way 4.19.6* for pilot and fishing craft are for the guidance of the Builder and subsequent Owners/operators of the craft. Where the intended service for either of these types of craft, or other types of craft which may be subject to loadings resulting from contact with other craft, jetties or similar loading or boarding facilities, is such that the loadings are greater than those that can be satisfactorily distributed into the craft's structure by the arrangements indicated, the strengthening arrangements are to be increased accordingly.

3.6.5 For **pilot craft** and other general workboats which may be subject to repeated impact loadings from contact with other craft, etc. the sheerstrake laminate and stiffening arrangements in way are to be increased locally. An increase in laminate weight of not less than 50 per cent of the side shell laminate weight is to be fitted, extending in general from the bow aft over a distance of 0,33L_R or 500 mm aft of the point at which the craft reaches its greatest breadth, whichever is the greater, and around the quarters. The additional weight is to extend forward of the quarter and over the transom for a distance of 0,075L_R or 1,0 m, whichever is the greater. This reinforcement is in general to extend from the deck edge to below the first longitudinal stiffener, or a vertical distance equivalent to 1/3 the freeboard height, whichever is the greater. The additional laminate weight is then to be tapered out to the side shell laminate weight in accordance with the Rules, *see Pt 8, Ch 3, 3.14 Local reinforcement 3.14.2*. For increase in stiffening arrangements, *see Pt 8, Ch 3, 4.19 Fenders and reinforcement in way*. Where the side shell is of sandwich construction then in way of the sheerstrake the two skins of the sandwich are to combine and form a single skin. The weight of this single skin is to be the Rule single skin reinforced in accordance with the above or 1,5 times the total sandwich skin laminate weight whichever is the greater. The arrangement and distribution of this additional laminate between the skins in way of the taper is to be in accordance with *Pt 8, Ch 3, 3.2 Keel plate 3.2.4*. Where fendering can be considered to act as a chine/spray rail the extent of bottom shell laminate is, in general, to be to above the lower fender.

3.6.6 **Fishing craft** are, in general, to have their shell laminate as required to satisfy the Rule loadings, increased by 20 per cent. Additionally the side shell is not to be taken as less than the bottom shell weight, and where there are gallows, gantries, nets, or lines etc. the laminate in way is to be further increased locally and/or suitably protected by sheathing in timber, steel or other means. Where the hull is of sandwich construction in way of the sheerstrake the laminate is to combine to form a single skin as indicated in *Pt 8, Ch 3, 3.6 Sheerstrake 3.6.2*.

3.6.7 Individual consideration will be given to lesser scantlings than those required by *Pt 8, Ch 3, 3.6 Sheerstrake 3.6.3* for fishing craft used for pleasure, light duties, etc. Details of the service are to be submitted for appraisal.

3.7 Transom boundary reinforcement

3.7.1 Additional reinforcement is to be moulded into the transom boundary.

3.7.2 For single skin construction, the total weight of reinforcement is to be not less than twice the weight of the adjacent side shell plate laminate, but need not be greater than Rule keel weight as required by *Pt 8, Ch 3, 3.2 Keel plate*.

3.8 Chine reinforcement

3.8.1 Additional reinforcement is to be moulded into the chine line knuckle boundary, chines and other areas where there is a change of section.

3.8.2 The chine line knuckle is to be reinforced as required by *Pt 8, Ch 3, 3.7 Transom boundary reinforcement* for the transom boundary.

3.8.3 Chine details are to be such that the continuity of structural strength across the panel is maintained. Details of all chines are to submitted for consideration, *see also* LR's *Guidance Notes for Structural Details*.

3.9 Skeg

3.9.1 The thickness of the skeg plating is, in general, to be not less than the thickness of the keel at bottom or 1,5 times the thickness of the bottom shell on the sides, whichever is the greater, *see also Pt 8, Ch 3, 5.10 Skeg construction*.

3.10 Shell openings

3.10.1 Openings are to have smooth edges and well rounded corners. Exposed edges in way of cut-outs in single skin/plate laminate are, in general, to be suitably sealed over laminating with not less than 2 x 450 g/m^2 CSM (or equivalent) reinforcements. Alternative arrangements demonstrating the equivalent protection to the ingress of moisture into the laminate will be individually considered in association provided on the relevant plans.

3.10.2 The exposed edges of all openings cut in sandwich panels are to be suitably sealed. In general a high density foam core (or equivalent material) is to be used around the perimeter of such openings. Exposed edges in way of cut-outs in sandwich panels are to be overlaminated with a weight of laminate not less than that required for the outer skin of the sandwich panel.

3.10.3 Where other than an epoxy resin system is used the first layer of reinforcement, as required by *Pt 8, Ch 3, 3.10 Shell openings 3.10.1* and *Pt 8, Ch 3, 3.10 Shell openings 3.10.2*, is, in general, to be CSM with a weight not exceeding 300 g/m^2.

3.10.4 Sea inlet boxes are to have well rounded corners and, so far as possible are to be kept clear of the bilge radius. Arrangements are to be made to maintain the continuity of structural strength in way of the openings.

3.11 Appendages

3.11.1 The scantlings of appendages will be subject to special consideration on the basis of the Rules and the design loadings anticipated, but are in no case to be taken as less than that of the surrounding structure.

3.12 Fin and tuck

3.12.1 Additional reinforcement is to be moulded into the fin and tuck areas of yachts which have either internal fixed ballast or external attached ballast keels, *see also Pt 16 Control and Electrical Engineering*.

3.12.2 For single skin construction the total weight of reinforcement is not to be less than 1,50 times the weight of the adjacent bottom shell plate laminate, but need not be greater than the Rule keel weight as required by *Pt 8, Ch 3, 3.2 Keel plate*.

3.13 Transom

3.13.1 The thickness of the stern or transom is to be not less than that required by *Pt 8, Ch 3, 3.4 Bottom* and *Pt 8, Ch 3, 3.5 Side* as appropriate. Where water jet or sterndrive units are fitted, the scantlings of the plating in way of the nozzles and connections will be specially considered.

3.14 Local reinforcement

3.14.1 The hull and deck are to be locally increased in thickness in way of fittings for rudder tubes, propeller brackets, passenger routes, vehicle lanes, etc. The amount of increase is to be not less than 50 per cent of the adjacent plate laminate. Details of such reinforcement are to be submitted.

3.14.2 Local reinforcement is in general to extend under the adjacent supporting structure and then be tapered gradually to the base laminate thickness over a distance of not less than 20 times the difference in thickness, *see Figure 3.3.3 Arrangement of local reinforcement*.

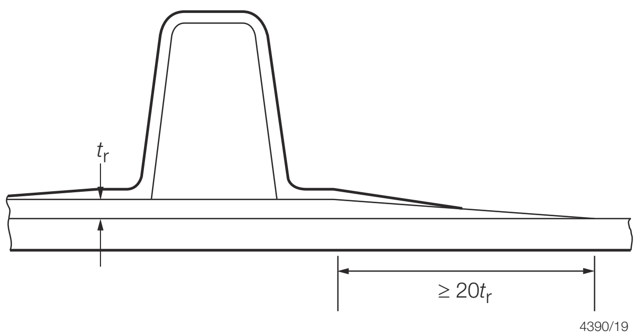


Figure 3.3.3 Arrangement of local reinforcement

3.14.3 The amount of material laid ‘wet on wet’ is to be limited to avoid excessive heat generation.

3.15 Hull laminate arrangement

3.15.1 The hulls of all craft with a service speed of 25 knots or greater are to be moulded, such that following local impact, damage progressive stripping of surface reinforcements will not occur. This may be achieved by arranging all hull reinforcements as shown in *Figure 3.3.4 Arrangement of hull reinforcement*.

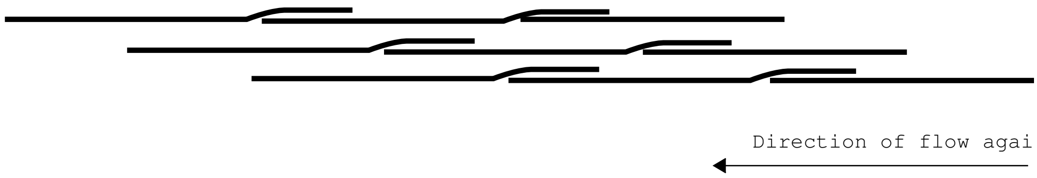


Figure 3.3.4 Arrangement of hull reinforcement

3.15.2 Details of the laminate sequence and direction of orientation are to be indicated in the laminate schedule as required by *Pt 8, Ch 2, 3.3 Laminating 3.3.7*.

3.15.3 It is recommended that woven reinforcements be laid transversely to minimise the susceptibility to progressive stripping of hull laminates following local impact.

3.15.4 Special consideration is to be given to hull laminates where high glass content is proposed and where orthophthalic resins are used.

3.16 Novel features

3.16.1 Where the Rules do not specifically define the requirements for novel features then the scantlings and arrangements are to be determined by direct calculations. Such calculations are to be carried out on the basis of the Rules, recognised standards and good practice, and are to be submitted for appraisal.

■ *Section 4* Shell envelope framing

4.1 Application

4.1.1 The requirements in this Section apply to longitudinally and transversely framed shell envelopes.

4.2 General

4.2.1 To determine the required scantlings, the formulae indicated in *Pt 8, Ch 3, 1.15 Stiffeners general* are, in general, to be used in conjunction with the design loadings specified in *Pt 5 Design and Load Criteria*.

4.3 Symbols and definitions

4.3.1 Symbols and definitions for use throughout this Chapter are as given in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1* or specified in the appropriate Section.

4.4 Bottom longitudinal stiffeners

4.4.1 The bottom longitudinals are to be supported by bottom transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.4.2 Bottom longitudinals are to be continuous through the supporting structures.

4.4.3 Where it is impracticable to comply with the requirements of *Pt 8, Ch 3, 4.4 Bottom longitudinal stiffeners 4.4.2*, or where it is desired to terminate the bottom longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets.

4.4.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate, and the coefficients Φ_M, Φ_S and Φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* for the load model (b).

4.4.5 The allowable tensile, compressive and shear stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* , and the span/deflection ratios indicated in *Table 7.2.1 Limiting span/deflection ratio* are to be complied with.

4.5 Bottom longitudinal primary stiffeners

4.5.1 Bottom longitudinal primary stiffeners are to be supported by bottom deep transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 6 m apart.

4.5.2 Bottom longitudinal primary stiffeners are to maintain their continuity through the supporting structures.

4.5.3 Where it is impracticable to comply with the requirements of *Pt 8, Ch 3, 4.5 Bottom longitudinal primary stiffeners 4.5.2*, or where it is desired to terminate the bottom longitudinal primary stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets. All brackets are to be `soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.5.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate, and the coefficients Φ_M, Φ_S and Φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* for the load model (a).

4.5.5 The allowable tensile, compressive and shear stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* , and the span/deflection ratios indicated in *Table 7.2.1 Limiting span/deflection ratio* are to be complied with.

4.6 Bottom transverse stiffeners

4.6.1 Bottom transverse stiffeners are defined as local stiffening members which support the bottom shell, and which may be continuous or intercostal.

4.6.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate, and the coefficients Φ_M, Φ_S and Φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* for the load model (b).

4.6.3 The allowable tensile, compressive and shear stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* , and the span/deflection ratios indicated in *Table 7.2.1 Limiting span/deflection ratio* are to be complied with.

4.7 Bottom transverse frames

4.7.1 Bottom transverse frames are defined as stiffening members which support the bottom shell, they are to be effectively continuous and be bracketed at their end connections to side frames and bottom floors as appropriate.

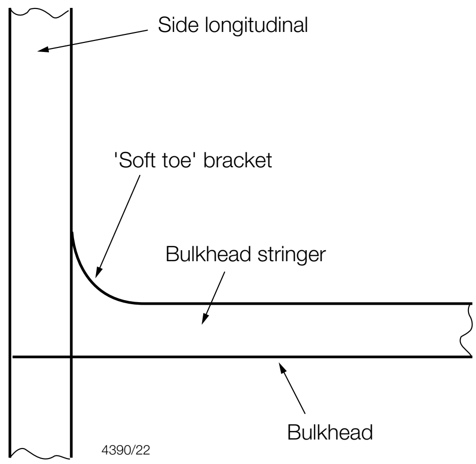
4.7.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate, and the coefficients Φ_M, Φ_S and Φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* for the load model (a).

4.7.3 The allowable tensile, compressive and shear stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* , and the span/deflection ratios indicated in *Table 7.2.1 Limiting span/deflection ratio* are to be complied with.

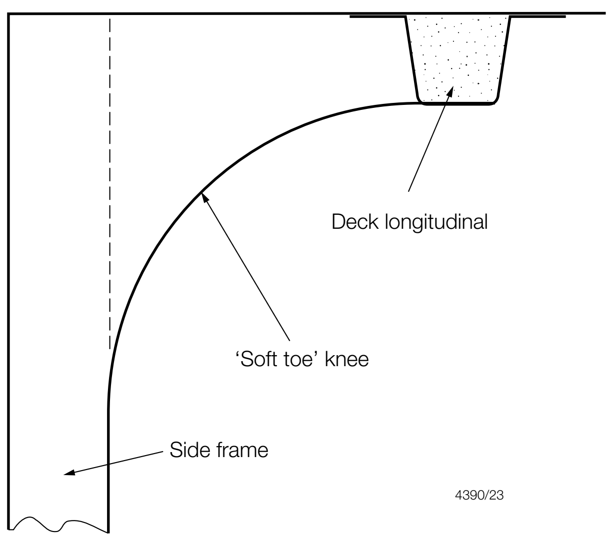
4.8 Bottom transverse web frames

4.8.1 Bottom transverse web frames are defined as primary stiffening members which support bottom shell longitudinals, they are to be continuous and be substantially bracketed at their end connections to side web frames and bottom floors.

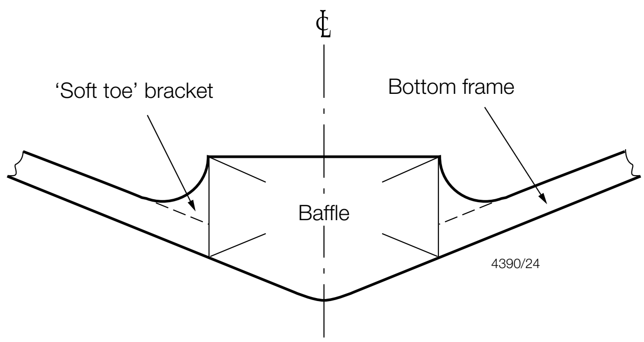
4.8.2 Where it is impracticable to comply with the requirements of *Pt 8, Ch 3, 4.8 Bottom transverse web frames 4.8.1*, or where it is desired to terminate the bottom transverse web frames in way of bulkheads or integral tank boundaries, etc. they are to be bracketed in way of their end connections, to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets. All brackets are to be `soft toed', *see Figure 3.4.1 `Soft-toe'* and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.



(a) Plan



(b) Section



(c) Section

Figure 3.4.1 `Soft-toe'

4.8.3 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate, and the coefficients Φ_M, Φ_S and Φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* for the load model (a).

4.8.4 The allowable tensile, compressive and shear stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* , and the span/deflection ratios indicated in *Table 7.2.1 Limiting span/deflection ratio* are to be complied with.

4.9 Side longitudinal stiffeners

4.9.1 The side longitudinals are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.9.2 Side longitudinals are to be continuous through the supporting structures.

4.9.3 Where it is impracticable to comply with the requirements of *Pt 8, Ch 3, 4.9 Side longitudinal stiffeners 4.9.2*, or where it is desired to terminate the side longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets.

4.9.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate, and the coefficients Φ_M, Φ_S and Φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* for the load model (b).

4.9.5 The allowable tensile, compressive and shear stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* , and the span/deflection ratios indicated in *Table 7.2.1 Limiting span/deflection ratio* are to be complied with.

4.10 Side longitudinal primary stiffeners

4.10.1 Side longitudinal primary stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 6 m apart.

4.10.2 Side longitudinal primary stiffeners are to maintain their continuity through the transverse bulkheads and other supporting structures.

4.10.3 Where it is impracticable to comply with the requirements of *Pt 8, Ch 3, 4.10 Side longitudinal primary stiffeners 4.10.2*, or where it is desired to terminate the side longitudinal primary stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets. All brackets are to be `soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.10.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate, and the coefficients Φ_M, Φ_S and Φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* for the load model (a).

4.10.5 The allowable tensile, compressive and shear stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* , and the span/deflection ratios indicated in *Table 7.2.1 Limiting span/deflection ratio* are to be complied with.

4.11 Side transverse stiffeners

4.11.1 Side transverse stiffeners are defined as local stiffening members which support the side shell, and which may be continuous or intercostal.

4.11.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate, and the coefficients Φ_M, Φ_S and Φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* for the load model (b).

4.11.3 The allowable tensile, compressive and shear stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* , and the span/deflection ratios indicated in *Table 7.2.1 Limiting span/deflection ratio* are to be complied with

4.12 Side transverse frames

4.12.1 Side transverse frames are defined as stiffening members supporting the side shell and spanning continuously between bottom floors/frames and decks. They are to be effectively constrained against rotation at their end connections.

4.12.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate, and the coefficients Φ_M, Φ_S and Φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* for the load model (a).

4.12.3 The allowable tensile, compressive and shear stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* , and the span/deflection ratios indicated in *Table 7.2.1 Limiting span/deflection ratio* are to be complied with.

4.13 Side transverse web frames

4.13.1 Side transverse web frames are defined as primary stiffening members which support side shell longitudinals, they are to be continuous and be substantially bracketed at their head and heel connections to deck beams and bottom web frames respectively.

4.13.2 Where it is impracticable to comply with the requirements of *Pt 8, Ch 3, 4.13 Side transverse web frames 4.13.1*, or where it is desired to terminate the side transverse web frames in way of side longitudinal primary stiffeners, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections, to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets. All brackets are to be `soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.13.3 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate, and the coefficients Φ_M, Φ_S and Φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* for the load model (a).

4.13.4 The allowable tensile, compressive and shear stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* , and the span/deflection ratios indicated in *Table 7.2.1 Limiting span/deflection ratio* are to be complied with.

4.14 Grouped frames

4.14.1 For the purposes of satisfying Rule requirements, frames may, subject to agreement by LR, be grouped. The number of frames in any group shall not in general exceed five. The summation of section stiffness, $E\ I$, for the group of frames is not to be less than the summation of the Rule requirements for the individual framing members. In addition, in no case is the proposed scantlings of an individual framing member within the group to be less than ninety per cent of the Rule value for that member.

4.15 Grillage structures

4.15.1 For complex girder systems, a complete structural analysis using numerical methods may have to be performed to demonstrate that the stress levels are acceptable when subjected to the most severe and realistic combination of loading conditions intended, *see also Pt 8, Ch 3, 1.3 Direct calculations*.

4.15.2 General or special purpose computer programs or any other analytical techniques may be used provided that the effects of bending, shear, axial and torsion are properly accounted for and the theory and idealisation used can be justified.

4.15.3 In general, grillages consisting of slender girders may be idealised as frames based on beam theory provided proper account of the variations of geometric properties is taken. For cases where such an assumption is not applicable, finite element analysis or equivalent methods may have to be used.

4.16 Combined framing systems

4.16.1 Where longitudinal and transverse primary stiffeners form grillage structures the scantlings may be derived in accordance with *Pt 8, Ch 3, 4.15 Grillage structures*.

4.17 Floating framing systems

4.17.1 Where the floating frame system is used, the effect of the plating attached to the stiffening members is to be ignored when calculating the required section stiffness, $E\ I$, of the primary stiffening members, i.e. the full section stiffness, $E\ I$, is to be provided by the primary stiffening member only.

4.18 Frame struts

4.18.1 Where struts are fitted to side shell transverse web frames or longitudinal primary stiffeners to carry axial loads the strut cross-sectional area is to be derived as for pillars in *Pt 8, Ch 3, 10 Pillars and pillar bulkheads*. If fitted at the stiffener half span point the stiffener section modulus may be taken as half the modulus derived from the general equations for the stiffening member being considered.

4.18.2 Design of end connections is to be such that the strut loads can be efficiently transmitted into the supporting structure.

4.19 Fenders and reinforcement in way

4.19.1 The design of and responsibility for the fendering on any craft rests with the designer and prospective Owner and are outside the scope of classification scantling approval requirements. The arrangement for fendering fitted should not be detrimental to the general working of the structure and therefore the requirements indicated in *Pt 8, Ch 3, 4.19 Fenders and reinforcement in way 4.19.2* are provided as recommendations of the areas requiring special consideration by the designer and Builder.

4.19.2 Wood belting and fenders, which may be subject to considerable impact load, are to be bedded down on a flexible sealing compound or a neoprene type gasket to ensure watertightness. The bolts are to be both adequate in number and size and, where practicable, reeled to prevent perforation of the laminate. Substantial plate washers or, where practicable, a continuous backing plate are to be provided. The arrangement for the attachment of the fender should, in general, be arranged so that where sections of the fender are damaged or torn, the watertight integrity of the hull is not impaired.

4.19.3 The laminate in way of such fittings is to be substantially increased in thickness to prevent overloading, and depending on the position, a back-up block of wood, plastic or metal may be required.

4.19.4 For craft such as pilot craft, fishing craft, etc. which may be subject to repeated impact loadings from contact with other craft whilst in service, due consideration is to be given to increasing the scantlings of stiffening members in way of the fenders. Details of these increased scantlings, anticipated loadings and calculations, are to be indicated on the submitted plans, *see also Pt 8, Ch 3, 3.6 Sheerstrake 3.6.3* and *Pt 8, Ch 3, 3.6 Sheerstrake 3.6.4*.

4.19.5 **Pilot craft** are, in general, to be fitted with large knees in way of the sheerstrake in areas as indicated in *Pt 8, Ch 3, 3.6 Sheerstrake 3.6.5*. The knees are to be aligned between the transverse frames and the deck beams. The thickness of the webs for these knees is to be twice that required by *Pt 8, Ch 3, 1.17 Stiffener proportions* or 6 mm at a fibre content by weight, of 0,5. Where the fibre content is less than 0,5 the minimum thickness is be increased by the factor k_c as follows:

$$t_{min} = 6k_c$$

where

k_c = 1,65–1,3 f_c

f_c is as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*.

In the case of longitudinally framed craft, web frames with knees are to be fitted at a spacing of generally no greater than 500 mm. A side longitudinal with a section modulus of, in general, twice that of the Rule longitudinal for the web frame spacing is to be positioned just below the lower fendering to carry the load associated with the dynamic loading from pitching and rolling. Consideration is also to be given to the termination of such brackets by use of a ‘soft-toe’ in way of the deck.

4.19.6 **Fishing craft** engaged in pair trawling and other modes of fishing, and which may be subject to repeated impact loading from contact with the other craft, are to have additional stiffening fitted in way of the impact areas. This may be in the form of large knees or intermediate knees, substantial fendering/rubbing strakes. Additionally, the shell and deck in way of all working areas are to be suitably sheathed.

■ *Section 5*
Single bottom structure and appendages

5.1 General

5.1.1 The requirements of this Section provide for single bottom construction of mono-hull craft in association with either transverse or longitudinal framing.

5.1.2 All girders are to extend as far forward and aft as practicable and care is to be taken to avoid any abrupt discontinuity particularly in way of skegs. Where girders are cut at bulkheads, their longitudinal strength is to be maintained.

5.1.3 Particular attention is to be taken to ensure that the continuity of structural strength in way of the intersection of transverse floors and longitudinal girders is maintained. The face reinforcement of such stiffening members is to be effectively continuous.

5.1.4 The single bottom structure in way of the keel, skeg and girders is to be sufficient to withstand the forces imposed by dry-docking the craft.

5.1.5 The breadth and thickness of plate keels are to comply with the requirements detailed in *Pt 8, Ch 3, 3.2 Keel plate*. *See also Pt 8, Ch 3, 3.9 Skeg 3.9.1*.

5.2 Centreline girder

5.2.1 In craft with single bottoms, a centreline girder is, in general, to be fitted in association with transverse frames, transverses supporting longitudinals or where the breadth of floors at the upper edge is greater than 1,5 m.

5.2.2 Centreline girders may be in the form of intercostal or continuous top hat or plate webs. Where the girder is intercostal, additional bracketing and local reinforcement as given in *Pt 8, Ch 3, 3.14 Local reinforcement* are to be provided to maintain the continuity of structural strength. The face reinforcement in all cases is to be continuous.

5.2.3 The web depth of the centre girder in general is to be equal to the depth of the floors at the centreline as specified in *Pt 8, Ch 3, 5.4 Floors, general*.

5.2.4 The web thickness, t_{w}, for a centre girder of `top-hat' type section is to be not less than that required by *Pt 8, Ch 3, 1.17 Stiffener proportions* or as determined as follows, whichever is the greater:

$$t_{\mathrm{w}} = 1,28\sqrt{k_{\mathrm{A}}}\left(\sqrt{L_{\mathrm{R}}} + 1\right) \text{ mm}$$

in no case is t_{w} to be taken less than 5,0 mm

where k_{A} and L_{R} are as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*.

5.2.5 The web thickness for a centre girder of single plate laminate construction is to be two times the thickness as required by *Pt 8, Ch 3, 5.2 Centreline girder 5.2.4*.

5.2.6 The face area of the centre girder, A_{f}, is to be not less than:

$$A_{\mathrm{f}} = 1,18 L_{\mathrm{R}} k_{\mathrm{A}} \text{ cm}^2$$

where k_{A} and L_{R} are as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*.

5.2.7 The face area of the centre girder outside 0,5*L* about midships may be reduced to 80 per cent of the value given in *Pt 8, Ch 3, 5.2 Centreline girder 5.2.6*.

5.2.8 The face thickness, t_{f}, is to be not less than the web thickness of the centre girder.

5.2.9 Additionally, the requirements of *Pt 8, Ch 3, 4.5 Bottom longitudinal primary stiffeners* for bottom longitudinal primary stiffeners are to be complied with.

5.3 Side girders

5.3.1 Where the floor breadth at the upper edge exceeds 6,0 m, side girders are to be fitted at each side of the centre girder such that the spacing between the side and centre girders or between the side girders themselves is not greater than 3 m. Side girders, where fitted, are to extend as far forward and aft as practicable and are, in general, to terminate in way of bulkheads, deep floors or other primary transverse structure.

5.3.2 In the engine room, additional side girders are generally to be fitted in way of the main machinery.

5.3.3 The face area of side girders, A_{f}, is not to be taken as less than:

$$A_{\mathrm{f}} = 0,82 L_{\mathrm{R}} \mathrm{k}_{\mathrm{A}} \text{ mm}$$

where k_{A} and L_{R} are as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*.

5.3.4 The face thickness, t_{f}, is not, in general, to be less than the web thickness of the side girder.

5.3.5 The web thickness, t_w, for side girders of `top-hat' type section is to be not less than as required by *Pt 8, Ch 3, 1.17 Stiffener proportions* or as determined as follows, whichever is the greater:

$$t_w = 1,28\sqrt{k_A L_R} \text{ mm}$$

where k_A and L_R are as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*

in no case is t_w to be taken less than 5,0 mm.

5.3.6 The web thickness for side girders of single plate laminate construction is to be two times the thickness as required by *Pt 8, Ch 3, 5.3 Side girders 5.3.5*.

5.3.7 In addition, the requirements of *Pt 8, Ch 3, 4.5 Bottom longitudinal primary stiffeners* for bottom longitudinal primary stiffeners are to be complied with.

5.3.8 Watertight side girders, or side girders forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deep tanks as detailed in *Pt 8, Ch 3, 7.3 Watertight bulkheads* and *Pt 8, Ch 3, 7.4 Deep tanks* respectively.

5.4 Floors, general

5.4.1 In transversely framed craft, floors are generally to be fitted at every frame and underneath each bulkhead.

5.4.2 In longitudinally framed craft, floors are to be fitted at every transverse web frame and bulkhead and generally at a spacing not exceeding 2 m. Additional transverse floors or webs are, in general, to be fitted at half web-frame spacing in way of engine seatings and thrust bearings, pillars, skegs, ballast/bilge keels and the bottom of the craft in the forefoot region.

5.4.3 The overall depth of transverse floors at the centreline, d_f, is not to be taken as less than:

when $B < 10$ m	$d_f = 40\,(B + 0{,}85D)$ mm
when $B \geq 10$ m	$d_f = 40\,(1{,}5B + 0{,}85D) - 200$ mm

where B is as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*.

5.4.4 The web thickness, t_w, for transverse floors of `top-hat' type section is to be not less than that required by *Pt 8, Ch 3, 1.17 Stiffener proportions* or as determined as follows, whichever is the greater:

$$t_w = \sqrt{k_A}\left(\frac{4,33d_f}{1000} + 2,75\right)\left(\frac{s}{1000} + 0,5\right) \text{mm}$$

where

d_f = is as defined in *Pt 8, Ch 3, 5.4 Floors, general 5.4.3*

k_A and s are defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*.

In no case is t_w to be taken less than 5,0 mm.

5.4.5 The web thickness for transverse floors of single plate laminate construction is to be two times the thickness as required by *Pt 8, Ch 3, 5.4 Floors, general 5.4.4*.

5.4.6 If side frames are attached to the floors by brackets, the depth of floor may be reduced by 15 per cent and the floor thickness determined using the reduced depth. The brackets are to have the same thickness as the floors, and their arm lengths clear of the frame are to be the same as the reduced floor depth given above.

5.4.7 The face area of floors, A_f, is not to be taken as less than:

$$A_f = 0,82 L_R k_A \text{ cm}^2$$

where k_A and L_R are as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*.

5.4.8 The thickness of the face reinforcement, t_f, is to be not less than the web thickness.

5.4.9 In addition, the requirements of *Pt 8, Ch 3, 4.8 Bottom transverse web frames* for bottom transverse web frames are to be complied with.

5.4.10 Floors are generally to be continuous from side to side.

5.4.11 The tops of floors, in general, may be level from side to side. However, in craft having considerable rise of floor the depth of the floor plate may require to be increased to maintain the required mechanical properties of the section.

5.4.12 The floors in the aft peak are to extend over and provide efficient support to the sterntube where applicable.

5.4.13 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deep tanks as detailed in *Pt 8, Ch 3, 7.3 Watertight bulkheads* or *Pt 8, Ch 3, 7.4 Deep tanks* respectively.

5.5 Floors in machinery spaces

5.5.1 Floors within machinery spaces are to comply with the requirements of *Pt 8, Ch 3, 5.4 Floors, general*.

5.5.2 The depth and mechanical properties of floors between engine or gearbox girders is to be not less than that required to maintain continuity of structural integrity or 50 per cent of the depth given in *Pt 8, Ch 3, 5.4 Floors, general 5.4.3*. The web thickness and face reinforcement weight of such reduced height floors are to be increased appropriately in order to maintain the continuity of structural strength.

5.6 Machinery seating

5.6.1 The general requirements for machinery seating are given in *Pt 3, Ch 2, 6.9 Machinery seatings*.

5.6.2 Main and auxiliary engines are to be effectively secured to the hull structure by seatings of adequate scantlings to resist the gravitational thrust, torque and vibration forces which may be imposed upon them.

5.6.3 The longitudinal girders forming the engine seating are to extend as far forward and aft as is practicable and are to be adequately supported by transverse floors or brackets.

5.6.4 Where stiffening is of plate construction, engine holding-down bolts are to be arranged as near as practicable to floors and longitudinal girders. When this cannot be achieved, bracket floors are to be fitted.

5.6.5 Machinery seatings are to be attached by means of primary bonding angles in accordance with *Pt 8, Ch 3, 1.19 Boundary bonding*.

5.7 Drainage arrangements

5.7.1 Suitable arrangements are to be made to provide free passage of air from all parts of the tanks to the air pipes, *see also Pt 9, Ch 1, 5 Securing of machinery*.

5.7.2 Sufficient limber holes are to be positioned in the internal bottom structure to allow for the drainage of water from all parts of the bilge to the pump suctions.

5.7.3 Particular attention is to be given to the positioning of limbers to ensure adequate drainage and to avoid stress concentrations. *See* LR's *Guidance Notes for Calculation Procedures for Composite Construction*.

5.7.4 Openings in the webs of stiffening sections, baffle plates, etc. are, in general, to be formed by moulded-in preforms under top hat type stiffening. Edges of openings in plate laminates are to be suitably sealed in accordance with *Pt 8, Ch 3, 1.30 Openings in the webs of stiffening members*.

5.8 Rudder horns

5.8.1 The scantlings of the rudder horn will be specially considered and in the case of high aspect ratio or novel designs direct calculations will be required to be submitted in accordance with *Pt 3, Ch 1, 2 Direct calculations*.

5.9 Sternframes

5.9.1 Where it is proposed to mould a composite sternframe, the scantlings and arrangements will be specially considered on the basis of direct calculations and loadings submitted by the Builders and designers.

5.10 Skeg construction

5.10.1 Skegs are to be effectively integrated into the adjacent structure and their design is to be such as to facilitate this, *see also Pt 8, Ch 3, 3.9 Skeg*.

5.10.2 The scantlings of skegs and the internal diaphragms at bulkheads and web frames are to be sufficient to withstand any docking forces to which they may be subjected.

5.11 Forefoot and stem

5.11.1 For craft of composite sandwich construction the forefoot region is to be so designed that in the event of local impact (*see also Pt 8, Ch 3, 2.8 Impact considerations*) with floating debris, the resultant damage will be limited. This may be achieved by:

(a) Arranging the individual plies of the laminate such that any delamination will be directed to the outer surface of the laminate, *see Figure 3.5.1 Arrangement of laminate in way of forefoot and stem*.

(b) The addition of a sacrificial `nose', *see Figure 3.5.2 `Sacrificial nose'*.

(c) By the addition of suitable sheathing, in accordance with *Pt 8, Ch 3, 2.9 Sheathing*.

(d) For vessels where the operating high speed waterline results in the exposure of the forefoot region, the laminate sequence in the keel area will be specially considered.

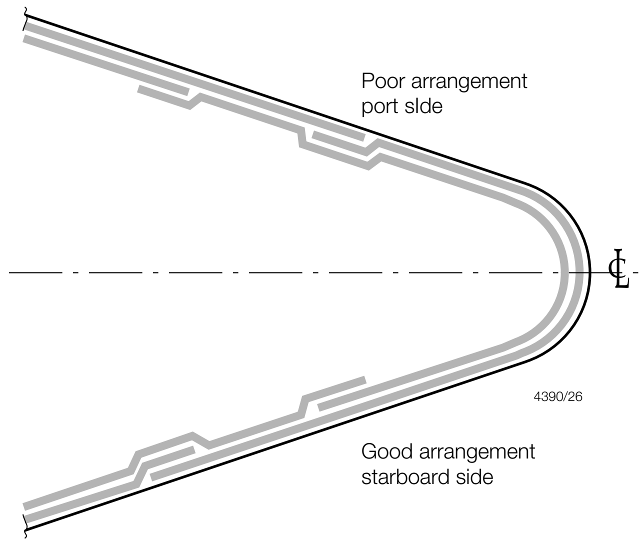


Figure 3.5.1 Arrangement of laminate in way of forefoot and stem

5.12 Transom knee

5.12.1 Centre and side girders are to be bracketed to the transom framing members by means of substantial knees. The face flat area of the girders may be gradually reduced to that of the transom stiffening member in accordance with *Figure 3.5.3 Transom knee*.

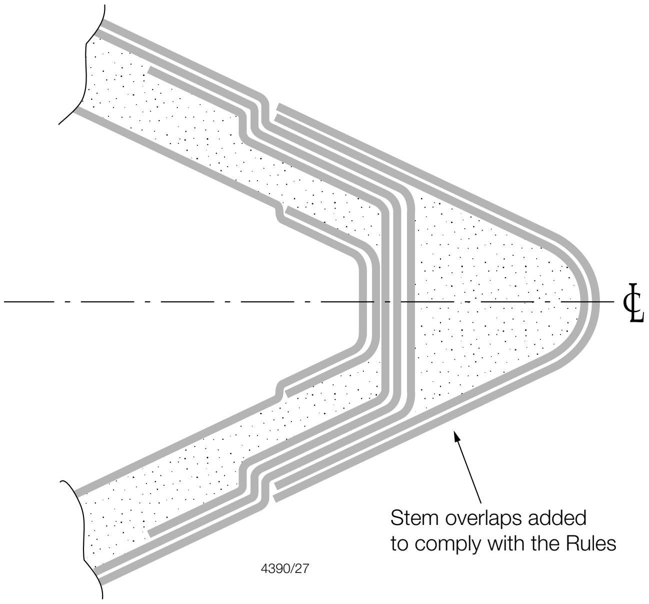


Figure 3.5.2 `Sacrificial nose'

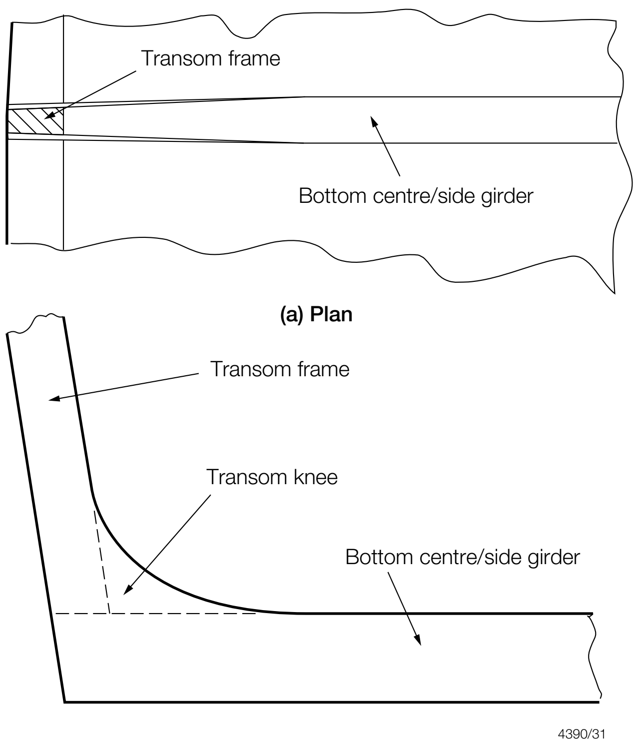


Figure 3.5.3 Transom knee

5.12.2 Hard spots are to be avoided in way of the end connection, and care taken to ensure that the stiffening member to which the transom knee is bracketed can satisfactorily carry the transmitted bending moment.

Section 6
Double bottom structure

6.1 General

6.1.1 The requirements given in this Section provide for double bottom construction of mono-hull craft in association with either transverse or longitudinal framing.

6.1.2 Where required in accordance with *Pt 3, Ch 2, 6 Machinery space arrangements*, double bottoms are generally to extend from the collision bulkhead to the after peak bulkhead, as far as this is practicable taking into account the design and proper working of the craft. In addition, the inner bottom is to be continued to the craft's side in such a manner as to protect the bottom to the turn of bilge or chine.

6.1.3 The double bottom structure in way of girders and duct keels is to be sufficient to withstand the forces imposed by dry-docking the craft.

6.1.4 The centreline girder and side girders are to extend as far forward and aft as practicable and care is to be taken to avoid any abrupt discontinuity. Where girders are cut at bulkheads, their longitudinal strength is to be maintained.

6.2 Keel

6.2.1 The breadth and thickness of plate keels are to comply with the requirements of *Pt 8, Ch 3, 3.2 Keel plate*.

6.3 Centreline girder

6.3.1 A centreline girder is to be fitted throughout the length of the craft. The web thickness, t_w, of a centreline girder of `top-hat' type section is to be not less than as required by *Pt 8, Ch 3, 1.17 Stiffener proportions*, or as determined as follows, whichever is the greater and in no case is t_w to be taken less than 5 mm.

$$t_w = \sqrt{k_A}\left(\frac{L_R}{8} + 3,64\right) \geq 5 \text{ mm}$$

where k_A and L_R are as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*.

6.3.2 The web thickness of a centreline girder of single plate laminate construction is to be two times the thickness as required by *Pt 8, Ch 3, 6.3 Centreline girder 6.3.1*.

6.3.3 The overall depth of the centre girder, d_{DB}, is not to be taken as less than 630 mm and is to be sufficient to give adequate access to all parts of the double bottom.

6.3.4 Additionally, the requirements of *Pt 8, Ch 3, 4.5 Bottom longitudinal primary stiffeners* for bottom longitudinal primary stiffeners are to be complied with.

6.4 Side girders

6.4.1 Where the breadth of the floor at the upper edge does not exceed 6,0 m, side girders are not required.

6.4.2 Where the breadth of the floor at the upper edge exceeds 6,0 m, side girders are to be fitted at each side of the centre girder such that the spacing between the side and centre girders or between the side girders themselves is not greater than 3 m. Side girders, where fitted, are to extend as far forward and aft as practicable and are, in general, to terminate in way of bulkheads, deep floors or other primary transverse structure.

6.4.3 Under the main engine, girders extending from the bottom to the top plate of the engine seating are to be fitted. The height of the girders is not to be less than the height of the floor. Engine holding-down bolts are to be arranged as near as practicable to the girders and floors. Where this cannot be achieved, bracket floors are to be fitted.

6.4.4 Side girders are to have a minimum web thickness, t_w, as required by *Pt 8, Ch 3, 1.17 Stiffener proportions*, but not less than as determined as follows whichever is the greater and in no case is t_w to be taken less than 5,0 mm:

$$t_w = \sqrt{k_A}\left(0,064 L_R + 4,32\right) \text{ mm}$$

where k_A and L_R are as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*

6.4.5 The face area and face thickness of side girders are to comply with the requirements for plate floors as defined in *Pt 8, Ch 3, 5.4 Floors, general 5.4.7* and *Pt 8, Ch 3, 5.4 Floors, general 5.4.8* respectively.

6.4.6 Additionally, the requirements of *Pt 8, Ch 3, 4.5 Bottom longitudinal primary stiffeners* for bottom longitudinal primary stiffeners are to be complied with.

6.5 Bracket floors

6.5.1 Between plate floors, the shell inner bottom plating is to be supported by bracket floors. The brackets are to have the same thickness as plate floors and, where they are of single skin laminate construction, are to be stiffened on the unsupported edge.

6.5.2 In longitudinally framed craft, the brackets are to extend from the centre or side girder and margin plate to the adjacent longitudinal, but in no case is the breadth of the bracket to be taken less than 3/4 of the depth of centre girder. Brackets are to be fitted at every web frame at the margin plate, and those at the centre girder are to be spaced not more than 1,0 m apart.

6.5.3 In transversely framed craft, the breadth of the brackets attaching the bottom and inner bottom frames to the centre girder and margin plate is to be not less than 3/4 of the depth of the centre girder.

6.6 Plate floors

6.6.1 Plate floors may be of single skin, sandwich skin or `top-hat' type construction.

6.6.2 The web thickness, t_w, for non-watertight plate floors of `top-hat' type section is to be not less than as required by *Pt 8, Ch 3, 1.17 Stiffener proportions*, or as determined as follows, whichever is the greater and in no case is t_w to be taken less than 5,0 mm.

$$t_w = \sqrt{k_A}\left(0,064L_R + 4,32\right) \text{ mm}$$

where k_A and L_R are as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*.

6.6.3 The web thickness for transverse floors of single plate laminate construction is to be two times the thickness as required by *Pt 8, Ch 3, 6.6 Plate floors 6.6.2*.

6.6.4 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of *Pt 8, Ch 3, 2.5 Minimum skin reinforcement in sandwich laminates 2.5.1*.

6.6.5 Additionally, the requirements of *Pt 8, Ch 3, 4.8 Bottom transverse web frames* for bottom transverse web frames are to be complied with.

6.6.6 Plate floors are generally to be continuous between the centre girder and the margin plate.

6.7 Watertight floors

6.7.1 The scantlings of watertight floors are to comply with the requirements for plate floors as detailed in *Pt 8, Ch 3, 6.6 Plate floors*.

6.7.2 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deep tanks as detailed in *Pt 8, Ch 3, 7.3 Watertight bulkheads* or *Pt 8, Ch 3, 7.4 Deep tanks* respectively.

6.8 Tankside brackets

6.8.1 The scantlings of tankside brackets are to comply with the requirements for plate floors as detailed in *Pt 8, Ch 3, 6.6 Plate floors*.

6.9 Inner bottom laminate

6.9.1 Inner bottom laminates forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deep tanks as detailed in *Pt 8, Ch 3, 7.3 Watertight bulkheads* or *Pt 8, Ch 3, 7.4 Deep tanks* respectively and, where forming vehicle, passenger or other decks the requirements of *Pt 8, Ch 3, 8 Deck Structures* are to be complied with.

6.9.2 The bending moment assumed to be carried by the inner bottom plating is to be not less than that determined from *Pt 8, Ch 3, 1.9 Plate and sandwich laminates 1.9.1*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by *Pt 8, Ch 3, 6.9 Inner bottom laminate 6.9.3* and *Pt 8, Ch 3, 6.9 Inner bottom laminate 6.9.5* respectively.

6.9.3 An estimate of the thickness of the **inner bottom single skin plating** is to be determined from *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.1*. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.3* and *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.4*, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* are to be complied with.

6.9.4 In no case is the minimum thickness of single skin plating to be taken as less than 5 mm.

6.9.5 An estimate of the stiffness $E\ I$, the thickness of single skin plating for **outer and inner skins of the bottom sandwich panel** and the thickness of core material is to be determined from *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.2* and *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.9* respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.7* and *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.8*. The allowable tensile and compressive stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* are to be complied with.

6.9.6 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of *Pt 8, Ch 3, 2.5 Minimum skin reinforcement in sandwich laminates 2.5.1*, *see Pt 8, Ch 3, 2.3 Sandwich skin laminate 2.3.1*.

6.9.7 Special consideration may be given to laminate thicknesses lesser than that required by *Pt 8, Ch 3, 6.9 Inner bottom laminate 6.9.4* and *Pt 8, Ch 3, 6.9 Inner bottom laminate 6.9.6*, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see Pt 8, Ch 3, 2.3 Sandwich skin laminate 2.3.1*, and the equivalent impact resistance is to be demonstrated as required by *Pt 8, Ch 3, 2.8 Impact considerations 2.8.2*.

6.10 Inner bottom longitudinals

6.10.1 The inner bottom longitudinals are to be supported by inner bottom transverse web frames, floors, bulkheads, or other primary structures, generally spaced not more than 2 m apart.

6.10.2 Inner bottom longitudinals are to be continuous through the supporting structures.

6.10.3 Where it is impracticable to comply with the requirements of *Pt 8, Ch 3, 6.10 Inner bottom longitudinals 6.10.2*, or where it is desired to terminate the inner bottom longitudinals in way of bulkheads or integral tank boundaries, the longitudinals are to be bracketed in way of their end connections, to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets.

6.10.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate, and the coefficients Φ_M, Φ_S and Φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* for the load model (b).

6.10.5 The allowable tensile, compressive and shear stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* , and the span/deflection ratios indicated in *Table 7.2.1 Limiting span/deflection ratio* are to be complied with.

6.11 Inner bottom transverse web framing

6.11.1 Inner bottom transverse web frames are defined as primary stiffening members which support inner bottom longitudinals. They are to be continuous and substantially bracketed at their end connections to bottom web frames, bottom floors and tankside brackets.

6.11.2 Where it is impracticable to comply with the requirements of *Pt 8, Ch 3, 6.11 Inner bottom transverse web framing 6.11.1*, or where it is desired to terminate the inner bottom transverse web frames in way of centre or side girders, bulkheads or integral tank boundaries, etc. all web frames are to be bracketed in way of their end connections, to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets. All brackets are to be `soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

6.11.3 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate, and the coefficients Φ_M, Φ_S and Φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* for the load model (a).

6.11.4 The allowable tensile, compressive and shear stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* , and the span/deflection ratios indicated in *Table 7.2.1 Limiting span/deflection ratio* are to be complied with.

6.12 Margin plates

6.12.1 A margin plate, if fitted, is to have a thickness as required for the inner bottom plating.

6.13 Wells

6.13.1 Small wells constructed in the double bottom are not to extend in depth more than necessary. A well extending to the outer bottom may, however, be permitted at the after end of the shaft tunnel of the craft. Other well arrangements (e.g. for lubricating oil under main engines) may be considered provided they give protection equivalent to that afforded by the double bottom.

6.14 Transmission of pillar loads

6.14.1 In double bottoms under widely spaced pillars, the connections of the floors to the girders, and of the floors and girders to the inner bottom, are to be suitably increased. Where pillars are not directly above the intersection of plate floors and girders, partial floors and intercostals are to be fitted as necessary to support the pillars. Manholes are not to be cut in the floors and girders below the heels of pillars. Where longitudinal framing is adopted in the double bottom, equivalent stiffening under the heels of pillars is to be provided, and where the heels of pillars are carried on a tunnel, suitable arrangements are to be made to support the load.

6.15 Drainage arrangements

6.15.1 Suitable arrangements are to be made to provide free passage of air and water from all parts of the tanks to the air pipes and pump suctions.

6.15.2 Particular attention is to be given to the positioning of limbers to ensure adequate drainage and to avoid stress concentrations, *see also Pt 8, Ch 3, 5.7 Drainage arrangements*.

6.15.3 Openings in the webs of stiffening sections, baffle plates, etc. are to be suitably sealed in accordance with *Pt 8, Ch 3, 4.16 Combined framing systems*.

6.16 Manholes

6.16.1 Sufficient manholes are to be cut in the inner bottom, floors and side girders to provide adequate access to and ventilation of all parts of the double bottom. The size of the manhole openings in plate laminates is not, in general, to exceed 50 per cent of the double bottom depth unless edge reinforcement is provided. Holes are, in general, not to be cut in the centre girder, except in tanks at the forward and after ends of the craft, and elsewhere where tank widths are reduced unless additional stiffening and/or compensation is fitted to maintain the structural integrity.

6.17 Pressure testing

6.17.1 Double bottoms are to be tested upon completion with a head of water representing the maximum internal pressure which could be experienced in service, but not less than a head of water equivalent to the level of the upper deck.

■ *Section 7*
Bulkheads and deep tanks

7.1 General

7.1.1 The requirements of this Section apply to craft with bulkheads of either sandwich or single skin composite construction.

7.1.2 Watertight and collision bulkheads are to be fitted in accordance with the requirements of *Pt 3, Ch 2, 4 Bulkhead arrangements*.

7.1.3 FRP composite bulkheads and plywood bulkheads are, where practicable, to be suitably attached to receiving frames, *see also* LR's *Guidance Notes for Structural Details*. The bulkheads are to be attached using double angles or equivalent, *see Pt 8, Ch 3, 1.19 Boundary bonding*. Proposals to fit bulkheads and tank boundaries on receiving strips in lieu of frames, will be individually considered.

7.1.4 Where bulkheads are of steel or aluminium construction, their scantlings and arrangements are to be in accordance with *Pt 6, Ch 3 Scantling Determination for Mono-Hull Craft* or *Pt 7, Ch 3 Scantling Determination for Mono-Hull Craft* respectively. The method of attachment to the framing will be specially considered.

7.1.5 For bulkheads in way of partially filled holds or tanks, sloshing forces may be required to be taken into account. Where such forces are likely to be significant, the scantlings will be required to be verified by additional calculations which are to be submitted with the plans.

7.1.6 In deep tanks which extend from side to side a centreline bulkhead is generally to be fitted. The bulkhead may be intact or perforated as desired. If intact the scantlings are to comply with the requirements of *Pt 8, Ch 3, 7.4 Deep tanks* and *Pt 8, Ch 3, 7.11 Wash plates* for tank boundary bulkheads. If perforated, they are to comply with the requirements of *Pt 8, Ch 3, 7.11 Wash plates* for washplates.

7.1.7 The scantlings of non-watertight or partial bulkheads are, in general, to be as required by *Pt 8, Ch 3, 7.3 Watertight bulkheads* for watertight bulkheads. Non-watertight or partial bulkheads supporting hull framing are to have scantlings equivalent to frames or web frames, in the same position, as appropriate.

7.2 Symbols and definitions.

7.2.1 The symbols and definitions for use within this Section are as given in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*.

7.3 Watertight bulkheads

7.3.1 Composite watertight bulkheads may be of sandwich construction, with or without stiffeners, or of single skin construction with closely spaced vertical or horizontal stiffeners. Where steel or aluminium alloy bulkheads are fitted, their scantlings and arrangements are to be in accordance with *Pt 6, Ch 3 Scantling Determination for Mono-Hull Craft* or *Pt 7, Ch 3 Scantling Determination for Mono-Hull Craft* respectively. Sandwich timber bulkheads, plywood bulkheads or other forms of bulkhead construction will be considered on the basis of equivalent strength and stiffness. Where bulkheads are of novel design they will be specially considered.

7.3.2 The bending moment assumed to be carried by the watertight bulkhead plating is to be not less than that determined from *Pt 8, Ch 3, 1.9 Plate and sandwich laminates 1.9.1*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* for both non-displacement or displacement type craft. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by *Pt 8, Ch 3, 7.3 Watertight bulkheads 7.3.3* and *Pt 8, Ch 3, 7.3 Watertight bulkheads 7.3.5* respectively.

7.3.3 An estimate of the thickness of watertight **bulkhead single skin plating** is to be determined from *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.1*. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.3* and *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.4*, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* are to be complied with.

7.3.4 In no case is the minimum thickness of single skin plating to be taken as less than 2,5 mm.

7.3.5 An estimate of the stiffness $E\,I$, thickness of single skin plating for outer and inner skins of the **bulkhead sandwich panel** and the thickness of core material is to be determined from *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.2* and *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.9* respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.7* and *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.8*. The allowable tensile and compressive stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* are to be complied with.

7.3.6 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of *Pt 8, Ch 3, 2.5 Minimum skin reinforcement in sandwich laminates 2.5.1*.

7.3.7 Special consideration may be given to laminate thicknesses lesser than that required by *Pt 8, Ch 3, 7.3 Watertight bulkheads 7.3.4* and *Pt 8, Ch 3, 7.3 Watertight bulkheads 7.3.6*, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see Pt 8, Ch 3, 2.3 Sandwich skin laminate 2.3.1*, and the equivalent impact resistance is demonstrated as required by *Pt 8, Ch 3, 2.8 Impact considerations 2.8.2*.

7.3.8 The Rule requirements for bending moment, shear force, shear stress and deflection for the bulkhead stiffeners are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* for both non-displacement or displacement type craft, and the coefficients Φ_M, Φ_S and Φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* for the appropriate load model.

7.3.9 The allowable tensile, compressive and shear stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* , and the span/deflection ratios indicated in *Table 7.2.1 Limiting span/deflection ratio* are to be complied with.

7.3.10 The geometric properties of stiffener sections are to be calculated in accordance with *Pt 8, Ch 3, 1.16 Geometric properties stiffener sections* using an effective width of attached plating as indicated in *Pt 8, Ch 3, 1.7 Effective width of attached plating*.

7.3.11 Bulkheads are to be suitably strengthened, if necessary, at the ends of deck girders and where subjected to concentrated loads.

7.3.12 Bulkheads in engine rooms that may be exposed to fuel oils are to be suitably protected against damage by fuel oil and by fire, *see Pt 8, Ch 3, 7.15 Fire protection*.

7.4 Deep tanks

7.4.1 Composite integral/deep tank bulkheads may be of sandwich construction with or without stiffeners, or of single skin with closely spaced vertical or horizontal stiffeners. Where steel or aluminium alloy integral/deep tank bulkheads are fitted, their scantlings and arrangements are to be in accordance with *Pt 6, Ch 3 Scantling Determination for Mono-Hull Craft* or *Pt 7, Ch 3 Scantling Determination for Mono-Hull Craft* respectively. Other forms of bulkhead construction will be considered on the basis of equivalent strength and stiffness. Where bulkheads are of novel design they will be specially considered.

7.4.2 A centreline bulkhead is, generally, to be fitted in deep tanks which extend from side to side of the craft. The bulkhead may be intact or perforated as desired. If intact, the plate scantlings are to be as required for boundary bulkheads.

7.4.3 The bending moment, M_b or M_c, as appropriate, assumed to be carried by the integral/deep tank bulkhead plating is to be not less than that determined from *Pt 8, Ch 3, 1.9 Plate and sandwich laminates 1.9.1*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* for both non-displacement or displacement type craft. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by *Pt 8, Ch 3, 7.4 Deep tanks 7.4.4* and *Pt 8, Ch 3, 7.4 Deep tanks 7.4.6* respectively.

7.4.4 An estimate of the thickness of **integral/deep tank bulkhead single skin plating** is to be determined from *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.1*. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.3* and *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.4*. The allowable tensile and compressive stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* are to be complied with.

7.4.5 In no case is the minimum thickness of single skin plating to be taken as less than 4,5 mm.

7.4.6 An estimate of the stiffness $E\ I$, thickness of single skin plating for outer and inner skins of **integral/deep tank bulkhead sandwich panels** and the thickness of core material is to be determined from *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.2* and *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.9* respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.7* and *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.8*. The allowable tensile and compressive stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* are to be complied with.

7.4.7 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of *Pt 8, Ch 3, 2.5 Minimum skin reinforcement in sandwich laminates 2.5.1*, *see Pt 8, Ch 3, 2.6 Integral tank structure 2.6.2*.

7.4.8 Special consideration may be given to laminate thicknesses less than that required by *Pt 8, Ch 3, 7.4 Deep tanks 7.4.5* and *Pt 8, Ch 3, 7.4 Deep tanks 7.4.7*, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see Pt 8, Ch 3, 2.3 Sandwich skin laminate 2.3.1*, and the equivalent impact resistance is demonstrated as required by *Pt 8, Ch 3, 2.8 Impact considerations 2.8.2*.

7.4.9 The Rule requirements for bending moment, shear force, shear stress and deflection for the integral/deep tank stiffeners are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* for both non-displacement or displacement type craft, and the coefficients Φ_M, Φ_S and Φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* for the load model (a).

7.4.10 The allowable tensile, compressive and shear stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* , and the span/deflection ratios indicated in *Table 7.2.1 Limiting span/deflection ratio* are to be complied with.

7.4.11 The geometric properties of stiffener sections are to be calculated in accordance with *Pt 8, Ch 3, 1.16 Geometric properties stiffener sections* using an effective width of attached plating as indicated in *Pt 8, Ch 3, 1.7 Effective width of attached plating*.

7.4.12 Integral/deep tank bulkheads are to be suitably strengthened, if necessary, at the ends of deck girders and where subjected to concentrated loads.

7.4.13 Integral/deep tank bulkheads in engine rooms that may be subjected to fuel oils are to be suitably protected against damage by fuel oil and by fire, *see Pt 8, Ch 3, 7.15 Fire protection*.

7.5 Double bottom tanks

7.5.1 The scantlings of double bottom tanks are to meet the structural requirements for deep tanks in accordance with *Pt 8, Ch 3, 7.4 Deep tanks*.

7.5.2 Where the crown of a double bottom tank forms a vehicle, passenger or other deck, the requirements of *Pt 8, Ch 3, 8 Deck Structures* are also to be complied with.

7.6 Collision bulkheads

7.6.1 The scantlings of composite collision bulkheads are to meet the requirements of *Pt 8, Ch 3, 7.3 Watertight bulkheads* but with allowable tensile, compressive and shear stress limits for collision bulkheads as indicated in *Table 7.3.1 Limiting stress criteria for local loading* in Chapter 7.

7.6.2 If the collision bulkhead forms the boundary of a deep tank or cofferdam the requirements of *Pt 8, Ch 3, 7.4 Deep tanks* are to be complied with.

7.7 Gastight bulkheads

7.7.1 Where gastight bulkheads are fitted, in accordance with *Pt 3, Ch 2, 4 Bulkhead arrangements*, their scantlings are to be as required for watertight bulkheads.

7.7.2 Gastight bulkheads are to be fitted to protect accommodation spaces from gases and vapour fumes from machinery, exhaust and fuel systems.

7.8 Plywood bulkheads

7.8.1 Plywood used for bulkheads is to be high quality marine plywood, and is to be in accordance with the requirements of *Pt 8, Ch 2, 2.17 Plywood*.

7.8.2 The structural requirements of plywood watertight bulkheads are to be as required by *Pt 8, Ch 3, 7.1 General*.

7.9 Non-watertight or partial bulkheads

7.9.1 Where a bulkhead is structural but non-watertight, the scantlings are, in general, to be as required for watertight bulkheads or equivalent in strength to web frames in the same position. Partial bulkheads that are non-structural are outside the scope of LR classification.

7.10 Stiffeners passing through bulkheads

7.10.1 Primary longitudinal stiffening members are to be continuous through transverse bulkheads.

7.10.2 Where a stiffener passes through a watertight bulkhead the bonding of the stiffener and compensation in way is to be not less than the laminate weight of the bulkhead.

7.10.3 Where structural members pass through the boundaries of watertight bulkheads or integral/deep tanks, and leakage into the adjacent space could be hazardous or undesirable, suitable cofferdams are to be built into the cores of top-hat stiffeners on each side of the boundary. The minimum thickness of such cofferdams is 4,5 mm.

7.10.4 Pipe or cable runs through watertight bulkheads are to be fitted with suitable watertight glands.

7.11 Wash plates

7.11.1 Tanks are to be subdivided as necessary by internal baffles or wash plates and the minimum thickness of the laminate for any internal structure is not, in general, to be less than 4,5 mm at a fibre content of 0,5 or equivalent thickness. Baffles or wash plates which support hull framing are to have scantlings equivalent to web frames in the same position.

7.11.2 Wash plates and wash bulkheads are, in general, to have an area of perforation not less than 10 per cent of the total area of the bulkhead. The perforations are to be so arranged that the efficiency of the bulkhead as a support is not impaired.

7.11.3 The plate thickness is to be not less than the structural element from which the wash bulkhead is formed.

7.12 Cofferdams

7.12.1 A cofferdam is to be fitted between fresh water and fuel oil or sanitary tanks. The scantlings of cofferdams are to comply with the requirements for deep tank bulkheads given in *Pt 8, Ch 3, 7.4 Deep tanks*.

7.13 Coatings

7.13.1 Fuel tanks are to incorporate a resin rich surface or be coated with an oil retardant resin on the internal exposed surfaces. Potable fresh water tanks are similarly to be coated with a suitable non-tainting resin.

7.14 Air pipes

7.14.1 Air pipes sufficient in number and area are to be fitted to each tank in accordance with *Pt 15, Ch 2, 11 Air, overflow and sounding pipes*.

7.15 Fire protection

7.15.1 Fire protection requirements as given in *Pt 17 Fire Protection, Detection and Extinction* are to be complied with.

7.16 Access

7.16.1 All compartments within the craft are to be accessible in order to facilitate proper maintenance and future structural surveys. Linings on craft-sides, deck-heads and bulkheads etc. must be capable of being removed. Similarly, sufficient space must be available below lower decks/soles to provide proper access to the bottom structure; an adequate number of manholes, removable panels, etc. are to be provided for this purpose.

7.16.2 Doors fitted through watertight bulkheads are to be of equivalent construction to the bulkhead in which they are fitted, permanently attached, capable of being closed watertight from both sides of the bulkhead and are to be tested watertight.

7.16.3 Doors or hatches are not to be fitted in collision bulkheads, except in craft of less than 21 m Rule length, L_R, or where it would be impracticable to arrange access to the forepeak other than through the collision bulkhead. Where fitted, such doors or hatches are to be watertight, as small as practicable and are to open into the forepeak compartment. Consideration will be given to operation from one side only. Doors or hatches in collision bulkheads are to be kept closed at all times while the craft is at sea.

7.16.4 Particular attention is to be given to the design and workmanship of adequate access manholes in tanks.

7.16.5 Where a manhole is fitted in a tank, the exposed edges of all openings cut in sandwich panels are to be suitably sealed. In general, a high density foam core (or equivalent material) is to be used around the perimeter of such openings. Exposed edges in way of cut-outs in sandwich panels are to be overlaminated with a weight of laminate not less than that required for the skin of the sandwich panel exposed to the fluid or as required by *Pt 8, Ch 3, 2.5 Minimum skin reinforcement in sandwich laminates 2.5.1*, whichever is the greater, *see Pt 8, Ch 3, 2.3 Sandwich skin laminate 2.3.1*.

7.16.6 Manhole covers are to be attached using bolts/studs spaced at not greater than six diameters. The cover is to be fitted on a suitable seal. Where studs or bolts used to attach the cover plate to the manhole pass through the laminate, they are to be suitably secured, sealed and over-laminated.

7.17 Testing

7.17.1 Integral/deep tanks are to be tested by air pressure or by a head of water. If tested by water, the head is to be either to 1,8 m above the crown of the tank or to the top of the air or overflow pipe, whichever is the greater. When tested by air, the pressure is not to exceed 0,014 N/mm^2. The head to which the tank will be subjected in service is to be indicated on the plans submitted.

Section 8
Deck Structures

8.1 General

8.1.1 The deck structure may be of either single skin or sandwich construction and is to be supported by transverse beams with fore and aft girders or by longitudinals with deep transverse beams.

8.1.2 Beams are to be fitted at each frame position and be bracketed to the side frames. Strong beams and deep transverse beams are to align with and be effectively connected to the side web frames. They are also to be fitted at the ends of large openings in the deck.

8.1.3 The ends of beams, longitudinals, girders and transverses are to be effectively built into the adjacent structure, or equivalent arrangements provided.

8.1.4 Primary stiffening members are to be continuous and substantially bracketed at their end connections to maintain continuity of structural strength.

8.1.5 Secondary stiffening members are to be effectively continuous and bracketed at their end connections as appropriate.

8.1.6 Deck structures subject to concentrated loads, such as pillars out of line, are to be suitably reinforced. Where concentrations of loading on one side of a stiffener may occur, the stiffener is to be adequately stiffened against torsion. Additional reinforcements may be required in way of localised areas of high stress.

8.1.7 Deck structures are to comply with the minimum thickness requirements of *Pt 8, Ch 3, 2 Minimum thickness requirements*.

8.1.8 Tripping brackets are to be fitted on deep webs.

8.2 Symbols and definitions

8.2.1 The symbols defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1* apply, unless otherwise specified.

8.3 Strength/weather deck laminate

8.3.1 The bending moment assumed to be carried by the strength/weather deck plating is to be not less than that determined from *Pt 8, Ch 3, 1.9 Plate and sandwich laminates 1.9.1*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by *Pt 8, Ch 3, 8.3 Strength/weather deck laminate 8.3.2* and *Pt 8, Ch 3, 8.3 Strength/weather deck laminate 8.3.4* respectively.

8.3.2 An estimate of the thickness of **strength/weather deck single skin plating** is to be determined from *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.1*. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.3* and *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.4*, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* are to be complied with.

8.3.3 In no case is the minimum thickness of single skin plating to be taken as less than 4 mm.

8.3.4 An estimate of the stiffness $E\,I$, thickness of single skin plating for outer and inner skins of the **strength/weather deck sandwich panels** and the thickness of core material is to be determined from *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.2* and *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.9* respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.7* and *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.8*. The allowable tensile and compressive stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* are to be complied with.

8.3.5 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of *Pt 8, Ch 3, 2.5 Minimum skin reinforcement in sandwich laminates 2.5.1*.

8.3.6 Special consideration may be given to laminate thicknesses lesser than that required by *Pt 8, Ch 3, 8.3 Strength/weather deck laminate 8.3.3* and *Pt 8, Ch 3, 8.3 Strength/weather deck laminate 8.3.5*, provided that all of the structural strength

requirements of the Rules are complied with, a satisfactory water barrier is provided, *see Pt 8, Ch 3, 2.3 Sandwich skin laminate 2.3.1*, and the equivalent impact resistance is demonstrated as required by *Pt 8, Ch 3, 2.8 Impact considerations 2.8.2*.

8.3.7 The scantlings of watertight cockpits are to be of equivalent strength to those for the strength/weather deck, *see also Pt 4 Additional Requirements for Yachts*.

8.3.8 It is recommended that working areas of the weather deck have an anti-slip surface.

8.3.9 Where decks are sheathed with wood or other materials, details of the method of attachment are to be submitted, *see also Pt 8, Ch 3, 2.9 Sheathing*.

8.4 Lower deck/inside deckhouse deck laminate

8.4.1 The bending moment assumed to be carried by the lower deck/inside deckhouse deck plating is to be not less than that determined from *Pt 8, Ch 3, 1.9 Plate and sandwich laminates 1.9.1*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by *Pt 8, Ch 3, 8.4 Lower deck/inside deckhouse deck laminate 8.4.2* and *Pt 8, Ch 3, 8.4 Lower deck/inside deckhouse deck laminate 8.4.4* respectively.

8.4.2 An estimate of the thickness of the **lower deck/inside deckhouse deck single skin plating** is to be determined from *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.1*. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.3* and *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.4*, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* are to be complied with.

8.4.3 In no case is the minimum thickness of single skin plating to be taken as less than 3 mm.

8.4.4 An estimate of the stiffness $E\,I$, thickness of single skin plating for outer and inner skins of the **lower deck/inside deckhouse deck sandwich panels** and the thickness of core material is to be determined from *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.2* and *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.9* respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.7* and *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.8*. The allowable tensile and compressive stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* are to be complied with.

8.4.5 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of *Pt 8, Ch 3, 2.5 Minimum skin reinforcement in sandwich laminates 2.5.1*.

8.4.6 Special consideration may be given to laminate thicknesses lesser than that required by *Pt 8, Ch 3, 8.4 Lower deck/inside deckhouse deck laminate 8.4.3* and *Pt 8, Ch 3, 8.4 Lower deck/inside deckhouse deck laminate 8.4.5*, provided that all of the structural strength requirements of the Rules are complied with.

8.5 Accommodation deck laminate

8.5.1 Accommodation decks are, in general, to be treated as lower deck/inside deckhouse decks, with their scantling requirements determined in accordance with *Pt 8, Ch 3, 8.4 Lower deck/inside deckhouse deck laminate*.

8.5.2 Sandwich timber, plywood or other forms of deck construction will be considered on the basis of equivalent strength and stiffness.

8.6 Cargo deck laminate

8.6.1 The bending moment assumed to be carried by the cargo deck plating is to be not less than that determined from *Pt 8, Ch 3, 1.9 Plate and sandwich laminates 1.9.1*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by *Pt 8, Ch 3, 8.6 Cargo deck laminate 8.6.2* and *Pt 8, Ch 3, 8.6 Cargo deck laminate 8.6.4* respectively.

8.6.2 An estimate of the thickness of the **cargo deck single skin plating** is to be determined from *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.1*. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using *Pt 8, Ch 3, 1.13 Determination of properties and stresses*

for single skin plate laminates 1.13.3 and *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.4*, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* are to be complied with.

8.6.3 In no case is the minimum thickness of single skin plating to be taken as less than 4 mm.

8.6.4 An estimate of the stiffness $E\ I$, thickness of single skin plating for outer and inner skins of the **cargo deck sandwich panels** and the thickness of core material is to be determined from *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.2* and *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.9* respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.7* and *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.8*. The allowable tensile and compressive stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* are to be complied with.

8.6.5 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of *Pt 8, Ch 3, 2.5 Minimum skin reinforcement in sandwich laminates 2.5.1*.

8.6.6 Special consideration may be given to laminate thicknesses lesser than that required by *Pt 8, Ch 3, 8.6 Cargo deck laminate 8.6.3* and *Pt 8, Ch 3, 8.6 Cargo deck laminate 8.6.5*, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see Pt 8, Ch 3, 2.3 Sandwich skin laminate 2.3.1*, and the equivalent impact resistance is demonstrated as required by *Pt 8, Ch 3, 2.8 Impact considerations 2.8.2*.

8.7 Decks forming crown of tanks

8.7.1 Decks forming the crowns of tanks are to comply with the requirements for the appropriate deck, and are to be additionally examined for compliance with the requirements for deep tanks given in *Pt 8, Ch 3, 7.4 Deep tanks*.

8.8 Strength/weather deck stiffening

8.8.1 The Rule requirements for bending moment, shear force, shear stress and deflection for the **strength/weather deck primary stiffeners** are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate, and the coefficients Φ_M, Φ_S and Φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* for the load model (a).

8.8.2 The Rule requirements for bending moment, shear force, shear stress and deflection for the **strength/weather deck secondary stiffeners** are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate, and the coefficients Φ_M, Φ_S and Φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.8.3 The allowable tensile, compressive and shear stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* , and the span/deflection ratios indicated in *Table 7.2.1 Limiting span/deflection ratio* are to be complied with.

8.8.4 The geometric properties of stiffener sections are to be calculated in accordance with *Pt 8, Ch 3, 1.16 Geometric properties stiffener sections* using an effective width of attached plating as given in *Pt 8, Ch 3, 1.7 Effective width of attached plating*.

8.9 Lower deck/inside deckhouse stiffening

8.9.1 The Rule requirements for bending moment, shear force, shear stress and deflection for the lower deck/inside deckhouse stiffeners are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate, and the coefficients Φ_M, Φ_S and Φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* for the appropriate load model. Primary members are assumed to be load model (a), secondary members are, in general, assumed to load model (b), however special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.9.2 The allowable tensile, compressive and shear stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* , and the span/deflection ratios indicated in *Table 7.2.1 Limiting span/deflection ratio* are to be complied with.

8.9.3 The geometric properties of stiffener sections are to be calculated in accordance with *Pt 8, Ch 3, 1.16 Geometric properties stiffener sections* using an effective width of attached plating as given in *Pt 8, Ch 3, 1.7 Effective width of attached plating*.

8.10 Accommodation deck stiffening

8.10.1 Accommodation decks are, in general, to be treated as lower deck/inside deckhouse decks, with their scantling requirements determined in accordance with *Pt 8, Ch 3, 8.9 Lower deck/inside deckhouse stiffening*.

8.11 Cargo decks

8.11.1 The Rule requirements for bending moment, shear force, shear stress and deflection for cargo deck stiffeners are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate, and the coefficients Φ_M, Φ_S and Φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* for the appropriate load model. Primary members are assumed to be load model (a), secondary members are, in general, assumed to be load model (b), however special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided. Additionally where the cargo comprises wheeled vehicles the requirements of *Pt 8, Ch 5, 3 Vehicle decks* are to be complied with.

8.11.2 The allowable tensile, compressive and shear stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* , and the span/deflection ratios indicated in *Table 7.2.1 Limiting span/deflection ratio* are to be complied with.

8.11.3 The geometric properties of stiffeners sections are to be calculated in accordance with *Pt 8, Ch 3, 1.16 Geometric properties stiffener sections* using an effective width of attached plating as given in *Pt 8, Ch 3, 1.7 Effective width of attached plating*.

8.12 Deck openings

8.12.1 All openings are to be supported by an adequate framing system, pillars or cantilevers. When cantilevers are used, stiffening requirements may be derived from direct calculations.

8.12.2 Where stiffening members are stopped in way of an opening, they are to be attached to carlings, girders, transverses or coamings.

8.12.3 The corners of large hatchways in the strength/weather deck within 0,5*L* amidships are to be elliptical, parabolic or rounded, with a radius generally not less than 1/24 of the breadth of the opening.

8.12.4 Where elliptical corners are arranged, the major axis is to be fore and aft, the ratio of the major to minor axis is to be not less than two to one, nor greater than 2,5 to 1, and the minimum half-length of the major axis is to be defined by l_1 in *Figure 3.8.1 Hatch opening geometry*. Where parabolic corners are arranged, the dimensions are also to be as shown in *Figure 3.8.1 Hatch opening geometry*.

8.12.5 Where the corners are parabolic or elliptical, increased thickness of laminate will, in general, not be required.

8.12.6 For other shapes of corner, reinforcement of the size and extent shown in *Figure 3.8.2 Reinforcement in way of hatch opening* will, in general, be required. The required weight of reinforcement is to be not less than 25 per cent greater than the adjacent deck laminate.

8.12.7 For lower decks the corners of large openings are to be rounded, with a radius generally not less than 1/24 of the breadth of the opening.

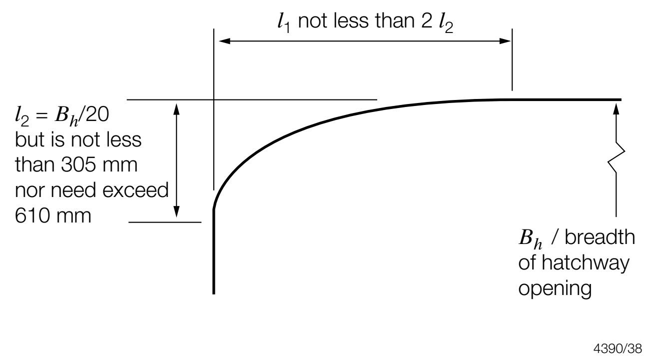


Figure 3.8.1 Hatch opening geometry

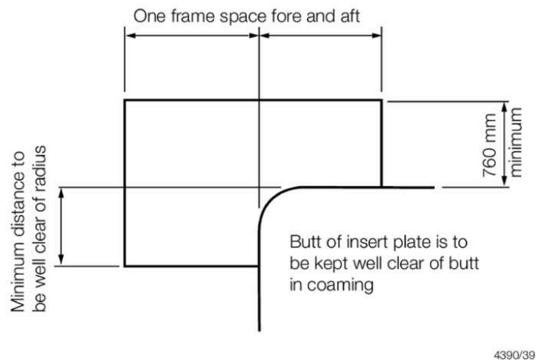


Figure 3.8.2 Reinforcement in way of hatch opening

8.12.8 Reinforcement as given in *Pt 8, Ch 3, 8.12 Deck openings 8.12.6* will be required at lower decks in way of rapid change in hull form to compensate for loss of deck cross-sectional area. Otherwise, reinforcement will not normally be required.

8.12.9 Adequate transverse strength is to be provided in the deck area between large hatch openings and subjected to transverse and buckling loads.

8.12.10 The requirements for closing arrangements and outfit are given in *Pt 3, Ch 4 Closing Arrangements and Outfit*.

8.13 Sheathing

8.13.1 The requirements for deck sheathing are given in *Pt 8, Ch 3, 2.9 Sheathing*.

8.14 Novel features

8.14.1 Novel features will be specially considered in accordance with *Pt 8, Ch 3, 2.7 Novel features*.

8.14.2 Where large or novel hatch openings are proposed, detailed calculations are to be submitted to demonstrate that the scantlings and arrangements in way of the openings are adequate to maintain continuity of structural strength.

■ *Section 9* Superstructures, deckhouses and bulwarks

9.1 General

9.1.1 Superstructures, deckhouses and bulwarks may be of single skin or sandwich construction or a combination of both.

9.1.2 Where practicable, superstructures and deckhouses are to be designed with well cambered decks and well radiused corners to build rigidity into the structure.

9.1.3 The laminate and supporting structure are to be suitably reinforced in way of stressed corners of openings, cranes, masts, derrick posts, machinery, fittings and other heavy or vibrating loads.

9.1.4 Primary stiffening members are to be continuous and substantially bracketed at their end connections to maintain continuity of structural strength.

9.1.5 Secondary stiffening members are, in general, to be continuous through supporting structures.

9.1.6 Structures subject to concentrated loads, such as pillars out of line, are to be suitably reinforced. Where concentrations of loading on one side of a stiffener may occur, the stiffener is to be adequately stiffened against torsion. Additional reinforcements may be required in way of localised areas of high stress.

9.1.7 Structures are to comply with the minimum thickness requirements of *Pt 8, Ch 3, 2 Minimum thickness requirements*.

9.1.8 Where a superstructure is fitted, the side shell plating, in way of the end of the superstructure, may be required to be increased in thickness, *see Pt 8, Ch 3, 3.14 Local reinforcement*.

9.2 Symbols and definitions

9.2.1 The term `house' is used in this Section to include both superstructures and deckhouses.

9.2.2 The symbols for use within this Section are as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*, unless otherwise specified.

9.3 House side laminates

9.3.1 The bending moment assumed to be carried by the house side plating is to be not less than that determined from *Pt 8, Ch 3, 1.9 Plate and sandwich laminates 1.9.1*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by *Pt 8, Ch 3, 9.3 House side laminates 9.3.2* and *Pt 8, Ch 3, 9.3 House side laminates 9.3.4* respectively.

9.3.2 An estimate of the thickness of **house side single skin plating** is to be determined from *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.1*. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.3* and *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.4*, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* are to be complied with.

9.3.3 In no case is the minimum thickness of single skin plating to be taken as less than 2,5 mm.

9.3.4 An estimate of the stiffness $E\,I$, thickness of single skin plating for outer and inner skins of the **house side sandwich panels** and the thickness of core material is to be determined from *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.2* and *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.9* respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.7* and *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.8*. The allowable tensile and compressive stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* are to be complied with.

9.3.5 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of *Pt 8, Ch 3, 2.5 Minimum skin reinforcement in sandwich laminates 2.5.1*.

9.4 House front laminates

9.4.1 The bending moment assumed to be carried by the house front plating is to be not less than that determined from *Pt 8, Ch 3, 1.9 Plate and sandwich laminates 1.9.1*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by *Pt 8, Ch 3, 9.4 House front laminates 9.4.2* and *Pt 8, Ch 3, 9.4 House front laminates 9.4.4* respectively.

9.4.2 An estimate of the thickness of **house front single skin plating** is to be determined from *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.1*. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.3* and *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.4*, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* are to be complied with.

9.4.3 In no case is the minimum thickness of single skin plating to be taken as less than 3,0 mm.

9.4.4 An estimate of the stiffness $E\,I$, the thickness of single skin plating for outer and inner skins of the **house front sandwich panels** and the thickness of core material is to be determined from *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.2* and *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.9* respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.7* and *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.8*. The allowable tensile and compressive stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* are to be complied with.

9.4.5 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of *Pt 8, Ch 3, 2.5 Minimum skin reinforcement in sandwich laminates 2.5.1*.

9.5 House aft end laminates

9.5.1 The bending moment assumed to be carried by the house aft end plating is to be not less than that determined from *Pt 8, Ch 3, 1.9 Plate and sandwich laminates 1.9.1*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by *Pt 8, Ch 3, 9.5 House aft end laminates 9.5.2* and *Pt 8, Ch 3, 9.5 House aft end laminates 9.5.4* respectively.

9.5.2 An estimate of the thickness of **house aft end single skin plating** is to be determined from *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.1*. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.3* and *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.4*, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* are to be complied with.

9.5.3 In no case is the minimum thickness of single skin plating to be taken as less than 2,5 mm.

9.5.4 An estimate of the stiffness $E\ I$, the thickness of single skin plating for outer and inner skins of the **house aft end sandwich panels** and the thickness of core material is to be determined from *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.2* and *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.9* respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.7* and *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.8*. The allowable tensile and compressive stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* are to be complied with.

9.5.5 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of *Pt 8, Ch 3, 2.5 Minimum skin reinforcement in sandwich laminates 2.5.1*.

9.6 House top laminates

9.6.1 The bending moment assumed to be carried by the house top plating is to be not less than that determined from *Pt 8, Ch 3, 1.9 Plate and sandwich laminates 1.9.1*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by *Pt 8, Ch 3, 9.6 House top laminates 9.6.3* and *Pt 8, Ch 3, 9.6 House top laminates 9.6.5* respectively.

9.6.2 An estimate of the thickness of **house top single skin plating** is to be determined from *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.1*. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.3* and *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.4*, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* are to be complied with.

9.6.3 In no case is the minimum thickness of single skin plating to be taken as less than 2,5 mm.

9.6.4 An estimate of the stiffness $E\ I$, the thickness of single skin plating for outer and inner skins of the **house top sandwich panels** and the thickness of core material is to be determined from *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.2* and *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.9* respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.7* and *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.8*. The allowable tensile and compressive stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* are to be complied with.

9.6.5 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of *Pt 8, Ch 3, 2.5 Minimum skin reinforcement in sandwich laminates 2.5.1*.

9.7 Coachroof laminates

9.7.1 The bending moment assumed to be carried by the coachroof plating is to be not less than that determined from *Pt 8, Ch 3, 1.9 Plate and sandwich laminates 1.9.1*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by *Pt 8, Ch 3, 9.7 Coachroof laminates 9.7.2* and *Pt 8, Ch 3, 9.7 Coachroof laminates 9.7.4* respectively.

9.7.2 An estimate of the thickness of **coachroof single skin plating** is to be determined from *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.1*. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.3* and *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.4*, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* are to be complied with.

9.7.3 In no case is the minimum thickness of single skin plating to be taken as less than 2,5 mm.

9.7.4 An estimate of the stiffness $E\ I$, thickness of single skin plating for outer and inner skins of the **coachroof sandwich panels** and the thickness of core material is to be determined from *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.2* and *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.9* respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.7* and *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.8*. The allowable tensile and compressive stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* are to be complied with.

9.7.5 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of *Pt 8, Ch 3, 2.5 Minimum skin reinforcement in sandwich laminates 2.5.1*.

9.8 Machinery casing laminates

9.8.1 The bending moment assumed to be carried by the machinery casing plating is to be not less than that determined from *Pt 8, Ch 3, 1.9 Plate and sandwich laminates 1.9.1*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by *Pt 8, Ch 3, 9.8 Machinery casing laminates 9.8.2* and *Pt 8, Ch 3, 9.8 Machinery casing laminates 9.8.4* respectively.

9.8.2 An estimate of the thickness of the **machinery casing single skin plating** is to be determined from *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.1*. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.3* and *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.4*, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits are indicated in *Table 7.3.1 Limiting stress criteria for local loading* for house side plating.

9.8.3 In no case is the minimum thickness of single skin plating to be taken as less than 3,0 mm.

9.8.4 An estimate of the stiffness $E\ I$, the thickness of single skin plating for outer and inner skins of the **machinery casing sandwich panels** and the thickness of core material is to be determined from *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.2* and *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.9* respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.7* and *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.8*. The allowable tensile and compressive stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* are to be complied with.

9.8.5 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of *Pt 8, Ch 3, 2.5 Minimum skin reinforcement in sandwich laminates 2.5.1*.

9.9 Forecastle requirements

9.9.1 The side laminate may be a continuation of the hull laminate, an integral part of the deck moulding or connected as a separate assembly. The laminate is to be the same weight as the side hull laminate at the deck edge position, and is to be increased along the connection, if fitted, to the top edge of the hull. Suitable scarfing arrangements are to be made to ensure the continuity of the effect of the sheerstrake at the break and at the upper edge of the forecastle side. The laminate is to be stiffened by sideframes carried up or they may be stopped short of the deck provided the ends are effectively built-in. Deep webs are to be fitted to ensure overall rigidity of the side laminate.

9.10 House side stiffeners

9.10.1 The Rule requirements for bending moment, shear force, shear stress and deflection for the **house side primary stiffeners** are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate, and the coefficients Φ_M, Φ_S and Φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* for the load model (a).

9.10.2 The Rule requirements for bending moment, shear force, shear stress and deflection for the **house side secondary stiffeners** are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate, and the coefficients Φ_M, Φ_S and Φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.10.3 The allowable tensile, compressive and shear stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* , and the span/deflection ratios indicated in *Table 7.2.1 Limiting span/deflection ratio* are to be complied with.

9.10.4 The geometric properties of stiffener sections are to be calculated in accordance with *Pt 8, Ch 3, 1.16 Geometric properties stiffener sections* using an effective width of attached plating as given in *Pt 8, Ch 3, 1.7 Effective width of attached plating*.

9.11 House front stiffeners

9.11.1 The Rule requirements for bending moment, shear force, shear stress and deflection for the **house front primary stiffeners** are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate, and the coefficients Φ_M, Φ_S and Φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* for the load model (a).

9.11.2 The Rule requirements for bending moment, shear force, shear stress and deflection for the **house front secondary stiffeners** are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate, and the coefficients Φ_M, Φ_S and Φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.11.3 The allowable tensile, compressive and shear stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* , and the span/deflection ratios indicated in *Table 7.2.1 Limiting span/deflection ratio* are to be complied with.

9.11.4 The geometric properties of stiffeners sections are to be calculated in accordance with *Pt 8, Ch 3, 1.16 Geometric properties stiffener sections* using an effective width of attached plating as given in *Pt 8, Ch 3, 1.7 Effective width of attached plating*.

9.12 House aft end stiffeners

9.12.1 The Rule requirements for bending moment, shear force, shear stress and deflection for the **house aft end primary stiffeners** are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate, and the coefficients Φ_M, Φ_S and Φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* for the load model (a).

9.12.2 The Rule requirements for bending moment, shear force, shear stress and deflection for the **house aft end secondary stiffeners** are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate, and the coefficients Φ_M, Φ_S and Φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.12.3 The allowable tensile, compressive and shear stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* , and the span/deflection ratios indicated in *Table 7.2.1 Limiting span/deflection ratio* are to be complied with.

9.12.4 The geometric properties of stiffener sections are to be calculated in accordance with *Pt 8, Ch 3, 1.16 Geometric properties stiffener sections* using an effective width of attached plating as given in *Pt 8, Ch 3, 1.7 Effective width of attached plating*.

9.13 House top stiffeners

9.13.1 The house top is to be efficiently supported by a system of transverse or longitudinal beams and girders. The span of the beams is generally not to exceed 2,4 m and the beams are to be effectively built into the house upper coamings and girders.

9.13.2 The Rule requirements for bending moment, shear force, shear stress and deflection for the **house top primary stiffeners** are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate, and the coefficients Φ_M, Φ_S and Φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* for the load model (a).

9.13.3 The Rule requirements for bending moment, shear force, shear stress and deflection for the **house top secondary stiffeners** are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate, and the coefficients Φ_M, Φ_S and Φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.13.4 The allowable tensile, compressive and shear stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* , and the span/deflection ratios indicated in *Table 7.2.1 Limiting span/deflection ratio* are to be complied with.

9.13.5 The geometric properties of stiffeners sections are to be calculated in accordance with *Pt 8, Ch 3, 1.16 Geometric properties stiffener sections* using an effective width of attached plating as given in *Pt 8, Ch 3, 1.7 Effective width of attached plating*.

9.14 Coachroof stiffeners

9.14.1 The Rule requirements for bending moment, shear force, shear stress and deflection for the **coachroof primary stiffeners** are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate, and the coefficients Φ_M, Φ_S and Φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* for the load model (a).

9.14.2 The Rule requirements for the bending moment, shear force, shear stress and deflection for the **coachroof secondary stiffeners** are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate, and the coefficients Φ_M, Φ_S and Φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.14.3 The allowable tensile, compressive and shear stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* , and the span/deflection ratios indicated in *Table 7.2.1 Limiting span/deflection ratio* are to be complied with.

9.14.4 The geometric properties of stiffener sections are to be calculated in accordance with *Pt 8, Ch 3, 1.16 Geometric properties stiffener sections* using an effective width of attached plating as given in *Pt 8, Ch 3, 1.7 Effective width of attached plating*.

9.15 Machinery casing stiffeners

9.15.1 The Rule requirements for bending moment, shear force, shear stress and deflection for the **machinery casing primary stiffeners** are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate, and the coefficients Φ_M, Φ_S and Φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* for the load model (a).

9.15.2 The Rule requirements for bending moment, shear force, shear stress and deflection for the **machinery casing secondary stiffeners** are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate, and the coefficients Φ_M, Φ_S and Φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.15.3 The allowable tensile, compressive and shear stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* , and the span/deflection ratios indicated in *Table 7.2.1 Limiting span/deflection ratio* are to be complied with.

9.15.4 Where casing sides act as girders supporting decks over, care is to be taken that access openings do not seriously weaken the structure. Openings are to be effectively framed and reinforced if found necessary. Particular attention is to be paid to stiffening where the casing supports the funnel or exhaust uptakes.

9.15.5 Where casing stiffeners carry loads from deck transverses, girders, etc. or where they are in line with pillars below, they are to be suitably reinforced.

9.15.6 The geometric properties of stiffener sections are to be calculated in accordance with *Pt 8, Ch 3, 1.16 Geometric properties stiffener sections* using an effective width of attached plating as given in *Pt 8, Ch 3, 1.7 Effective width of attached plating*.

9.16 Forecastle stiffeners

9.16.1 The Rule requirements for bending moment, shear force, shear stress and deflection for the **forecastle primary stiffeners** are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate, and the coefficients Φ_M, $\Phi_S$and Φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* for the load model (a).

9.16.2 The Rule requirements for bending moment, shear force, shear stress and deflection for the **forecastle secondary stiffeners** are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate, and the coefficients Φ_M, Φ_S and Φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.16.3 The allowable tensile, compressive and shear stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* , and the span/deflection ratios indicated in *Table 7.2.1 Limiting span/deflection ratio* are to be complied with.

9.16.4 The geometric properties of stiffener sections are to be calculated in accordance with *Pt 8, Ch 3, 1.16 Geometric properties stiffener sections* using an effective width of attached plating as given in *Pt 8, Ch 3, 1.7 Effective width of attached plating*.

9.17 Superstructures formed by extending side structure

9.17.1 Superstructure first tier sides formed by extending the hull side structure are to be in accordance with the requirements for house fronts indicated in *Pt 8, Ch 3, 9.4 House front laminates* and *Pt 8, Ch 3, 9.11 House front stiffeners* for laminates and stiffeners respectively, but need not be taken as greater than the side structure requirements at the deck edge at the same longitudinal position.

9.18 Fire aspects

9.18.1 Fire detection, protection and extinction requirements are given in *Pt 17 Fire Protection, Detection and Extinction*.

9.19 Openings

9.19.1 All openings are to be substantially framed and have well rounded corners. Arrangements are to be made to minimise the effect of discontinuities. Continuous coamings or girders are to be fitted below and above doors and similar openings.

9.19.2 Particular attention is to be paid to the effectiveness of end bulkheads when large openings for doors and windows are fitted, and also to the upper deck stiffening in way.

9.19.3 Special care is to be taken to minimise the size and number of openings in the side bulkheads in the region of the ends of houses within $0,5L_R$ amidships. Account is to be taken of the high vertical shear loading which may occur in these areas.

9.19.4 The requirements for closing arrangements and outfit are given in *Pt 3, Ch 4 Closing Arrangements and Outfit*.

9.20 Mullions

9.20.1 Window openings are to be suitably framed and mullions will in general be required.

9.20.2 The scantlings of mullions are to be not less than as required for a stiffener in the same position.

9.20.3 The geometric properties of stiffener sections are to be calculated in accordance with *Pt 8, Ch 3, 1.16 Geometric properties stiffener sections* using an effective width of attached plating as indicated in *Pt 8, Ch 3, 1.7 Effective width of attached plating*, in no case is the width of effective plating to be taken greater than the distance between adjacent window openings.

9.20.4 Where significant shear forces are to be transmitted by window frames, adequate shear rigidity requires to be verified.

9.21 Global strength

9.21.1 Transverse rigidity is to be maintained throughout the length of the house by means of web frames, bulkheads or partial bulkheads. Particular attention is to be paid when a superimposed tier is wider than its supporting tier and when significant loads are carried on the house top.

9.21.2 Where practicable, web frames are to be arranged in line with bulkheads below.

9.21.3 Internal bulkheads are to be fitted in line with bulkheads or deep primary stiffeners below.

9.22 House/deck connection

9.22.1 Adequate support under the ends of houses is to be provided in the form of webs, pillars, diaphragms or bulkheads in conjunction with reinforced deck beams.

9.22.2 Special attention is to be given to the connection of the house to the deck in order to provide an adequate load distribution and avoid stress concentrations.

9.22.3 Typical design details of house/deck connections are given in LR's *Guidance Notes for Structural Details*.

9.23 Sheathing

9.23.1 Sheathing arrangements are to comply with *Pt 8, Ch 3, 2.9 Sheathing*.

9.24 Novel features

9.24.1 Laminate and stiffener requirements may need to be determined by direct calculation where the house is of unusual design, form or proportions, *see also Pt 8, Ch 3, 2.7 Novel features*.

9.25 Bulwarks

9.25.1 General requirements for bulwarks are given in *Pt 3, Ch 4, 8 Bulwarks, guard rails and other means for the protection of crew*.

9.25.2 The bending moment assumed to be carried by the bulwark plating is to be not less than that determined from *Pt 8, Ch 3, 1.9 Plate and sandwich laminates 1.9.1*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by *Pt 8, Ch 3, 9.25 Bulwarks 9.25.3* and *Pt 8, Ch 3, 9.25 Bulwarks 9.25.5* respectively.

9.25.3 An estimate of the thickness of the **bulwark single skin plating** is to be determined from *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.1*. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.3* and *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.4*, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* are to be complied with.

9.25.4 In no case is the minimum thickness of single skin plating to be taken as less than 2,5 mm.

9.25.5 An estimate of the stiffness $E\ I$, thickness of single skin plating for outer and inner skins of the **bulwark sandwich panels** and the thickness of core material is to be determined from *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.2* and *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.9* respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.7* and *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.8*. The allowable tensile and compressive stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* are to be complied with.

9.25.6 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of *Pt 8, Ch 3, 2.5 Minimum skin reinforcement in sandwich laminates 2.5.1*.

9.25.7 The Rule requirements for bending moment, shear force, shear stress and deflection for the **bulwark stays** are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate, and the coefficients Φ_M, Φ_S and Φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* for the load model (d).

9.25.8 The allowable tensile, compressive and shear stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* , and the span/deflection ratios indicated in *Table 7.2.1 Limiting span/deflection ratio* are to be complied with.

9.25.9 The geometric properties of stiffener sections are to be calculated in accordance with *Pt 8, Ch 3, 1.16 Geometric properties stiffener sections* using an effective width of attached plating as given in *Pt 8, Ch 3, 1.7 Effective width of attached plating*.

9.25.10 Bulwarks should not be cut for gangway or other openings near the breaks of houses.

9.25.11 Attention is to be paid to avoid discontinuity of strength of the bulwark, particularly in way of local increases in stress and changes in height.

9.25.12 **Fishing craft** are to have bulwarks fitted. The bulwark may be formed as a continuation of the hull laminate, an integral part of the deck moulding or connected as a separate assembly. Where the bulwark is considered to be stressed and contributing to the global strength of the craft, the laminate weight of the bulwark is not to be less than the sheer laminate weight. In no case is the bulwark laminate weight to be taken as less than 80 per cent of the shell weight. The bulwark is to be supported by suitable stiffening which may be formed by a continuation of the side frames, or by top hat, or plate laminate stays of the same weight as the bulwark. These frames are not generally to be spaced more than two side frame spacings apart.

9.25.13 In way of gantries, trawl gallows, mooring pipes etc. the laminate in way is to be increased by 50 per cent.

9.25.14 **Pilot craft** are to be fitted with a suitable hand rail system adjacent to the exposed areas of the working decks and platforms and in addition these areas should have non skid surfaces. Where permitted by the Flag Administration, a suitable approved continuous safety rail system will be acceptable. Suitable operating procedures are to be in place for the trained crew.

9.26 Freeing arrangements

9.26.1 The requirements for freeing arrangements are given in *Pt 3, Ch 4, 9 Deck drainage*.

9.27 Free flow area

9.27.1 The requirements for free flow area are given in *Pt 3, Ch 4, 9.3 Free flow area*.

9.28 Guard rails

9.28.1 The requirements for guard rails are given in *Pt 3, Ch 4, 8.4 Guard rails*.

■ *Section 10* Pillars and pillar bulkheads

10.1 General

10.1.1 Pillars are to be arranged to transmit loads from decks and superstructures into the bottom structure. Pillars are to be constructed out of materials of adequate compressive strength and modulus, usually steel or aluminium and these are generally to be of solid, tubular or I beam form. A pillar may be a fabricated trunk or partial bulkhead.

10.2 Symbols and definitions

10.2.1 The symbols for use within this Section are as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*, unless otherwise specified in the appropriate sub-Section.

10.3 Determination of spans

10.3.1 The effective span length of pillar, l_{ep}, is in general the distance between the head and heel of pillar. Where substantial brackets are fitted, the effective length of pillar, l_{ep}, may be reduced by 2/3 of the depth of the brackets at each end.

10.4 Head and heel connection

10.4.1 The structure in way of head and heel connections is to be suitably reinforced. The webs and face reinforcement of such supporting structure are to be locally increased as necessary with due account being taken of both the compression and bending moment in way.

10.4.2 Pillars are to be attached at their heads and heels to plates supported by efficient brackets. Where the attachment is through bolted, suitable inserts or compression tubes are to be incorporated within the deck and hull framing to prevent over-compression and damage to the laminate in way. Alternatively, tapping plates may be incorporated within the face reinforcement of the stiffener. Details of the proposed arrangement are to be indicated on the submitted plans.

10.5 Alignment and arrangement

10.5.1 Pillars are to be fitted on main structural members. They should be fitted below deckhouses, windlasses, winches, capstans and elsewhere where considered necessary.

10.5.2 Wherever possible, deck pillars are to be fitted in the same vertical line as pillars above and below, and effective arrangements are to be made to distribute the load at the heads and heels of all pillars.

10.5.3 Where pillars support eccentric loads, or are subjected to lateral pressures, they are to be suitably strengthened for the additional bending moment imposed upon them.

10.6 Minimum thickness

10.6.1 The minimum wall thickness of steel or aluminium pillars are to be as required by *Pt 6, Ch 3 Scantling Determination for Mono-Hull Craft* or *Pt 7, Ch 3 Scantling Determination for Mono-Hull Craft* respectively.

10.6.2 The minimum wall thickness of FRP pillars will be specially considered.

10.7 Pillar scantlings

10.7.1 The scantlings of steel or aluminium pillars, and pillar bulkheads, are to be as required by *Pt 6, Ch 3 Scantling Determination for Mono-Hull Craft* and*Pt 7, Ch 3 Scantling Determination for Mono-Hull Craft* respectively.

10.7.2 The scantlings of FRP pillars/pillar bulkheads are to be in accordance with *Pt 8, Ch 3, 10.10 Composite pillars and pillar bulkhead scantlings*.

10.7.3 Where a pillar is of unusual material, the scantlings will be specially considered.

10.8 Pillars in tanks

10.8.1 Pillars are in no circumstances to pass through tanks. Where loads are to be transmitted through the tank, pillars within the tanks are to be carefully aligned with the external pillars.

10.8.2 Pillars within tanks are, in general, to be of solid cross section. Proposals to use hollow section or tubular pillars will be subject to special consideration and the scantlings as determined from the Rules may be required to be increased dependent upon the material to be used, the fluid contained and the arrangement of the pillars. Hollow pillars are to be adequately drained and vented.

10.8.3 Pillars within tanks which may be subjected to tensile stresses due to hydrostatic pressure, are to be designed to provide sufficient connection to withstand the tension load imposed.

10.9 Pillar bulkheads

10.9.1 Where the pillar bulkhead is of steel or aluminium construction the method of attachment to the surrounding structure/framing will be specially considered.

10.9.2 Where a pillar bulkhead supports a concentrated load the structure in way is to be suitably reinforced to distribute the load into the adjacent stiffening.

10.10 Composite pillars and pillar bulkhead scantlings

10.10.1 The load P_p, assumed to be carried by a pillar is to be determined from:

$$P_p = S_{gt} b_{gt} P_c + P_a \; kN$$

where

P_p = design load supported by the pillar, which is to be taken as not less than 5 kN

P_c = basic deck girder design pressure as appropriate, plus any other loadings above the pillar, in kN/m^2

where

P_a = load, in kN, from pillar or pillars above, assumed zero if there are no pillars over

S_{gt} = spacing, or mean spacing, of girders or transverses, in metres

b_{gt} = distance between centres of two adjacent spans of girders or transverses supported by the pillars, in metres

10.10.2 The load P_b, assumed to be carried by a pillar bulkhead is to be determined from:

$$P_{pb} = S_{bs} b_{pb} P_c + P_a \; kN$$

where

P_{pb} = design load supported by the stiffener plate combination of the pillar bulkhead, in kN

P_c = basic deck girder design pressure, as appropriate, plus any other loadings directly above the pillar, in kN/m^2

S_{bs} = spacing, or mean spacing of bulkheads or effective transverses/longitudinal stiffeners, in metres

b_{pb} = distance between centres of two adjacent spans of girders or transverses supported by the pillar bulkhead, in metres, and can be taken as the distance between pillar bulkhead stiffeners where the stiffener at the top of the bulkhead effectively distributes the load evenly into the stiffeners

10.10.3 The slenderness ratio (l_{ep}/r) of a pillar or plate stiffener combination is to be determined from:

$$r = \sqrt{\frac{\Sigma\left(E_i I_i\right)}{\Sigma\left(E_i A_i\right)}} \; cm$$

where

r = least radius of gyration of pillar cross section, in cm,

l_{ep} = effective length of pillar, in cm

E_i, I_i and A_i are as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*.

10.10.4 The compressive loads P_p or P_{pb}, from *Pt 8, Ch 3, 10.10 Composite pillars and pillar bulkhead scantlings 10.10.1* and *Pt 8, Ch 3, 10.10 Composite pillars and pillar bulkhead scantlings 10.10.2* for pillars and pillar bulkheads respectively are not to exceed a function of the critical load P_{cr}, determined from *Pt 8, Ch 3, 10.10 Composite pillars and pillar bulkhead scantlings 10.10.5*:

$$P_p\left(or \; P_{pb}\right) < f_p P_{cr} \; kN$$

where f_p is a factor dependent upon location and is as indicated in *Table 3.10.1 Pillar location factors*.

Table 3.10.1 Pillar location factors

Location	f_p
Supporting weatherdeck	0,50
Supporting vehicle deck	0,25
Supporting passenger deck	0,50
Supporting lower/inner deck	0,75
Supporting coachroof	0,75
Supporting deckhouse top	1,00

10.10.5 The critical compressive load, P_{cr}, for pillars and plate/stiffener combinations with a slenderness ratio (l_e/r) between 75 and 110 may be determined from:

$$P_{cr} = \frac{k\,\pi^2\,\Sigma\left(E_{ci} I_i\right)}{l_{ep}^{\ 2}}\,10^5 \;\; kN$$

where

l_{ep} = effective span length of pillar or stiffener plate combination, in metres

E_{ci} = compressive modulus of plate laminate, in N/mm^2

k = end fixity factor

= 1,5 for full fixed/bracketed

= 0,75 for partially fixed

= 0,5 for free ended

Where the proposed slenderness ratio is below 75 the pillar will be specially considered. Slenderness ratios in excess of 110 are not to be contemplated.

10.10.6 The stiffener/plate combination used to determine the scantlings for pillar bulkheads is to be that of a stiffener with an effective width of attached plating carrying a load as determined from *Pt 8, Ch 3, 1.7 Effective width of attached plating*.

10.10.7 The scantlings of wooden pillar bulkheads will be specially considered on the basis of the Rules. Such pillar bulkheads are to be of equivalent strength, stiffness and load carrying capability.

10.11 Detail in way of sandwich structure

10.11.1 The attachment of pillars to sandwich structures should, in general, be through an area of single skin laminate, *see Pt 8, Ch 2, 4.3 Inserts*. Where this is not practicable and the attachment of the pillar has to be by bolting through a sandwich structure then a wood, or other suitable solid insert is to be fitted in the core in way.

10.12 Fire aspects

10.12.1 Pillars are to be suitably protected against fire, where necessary, be self extinguishing or be capable of resisting fire damage. All pillars are to comply with *Pt 17 Fire Protection, Detection and Extinction*.

10.13 Novel features

10.13.1 Where pillars are of unusual design or constructed from novel material they will be specially considered in accordance with *Pt 8, Ch 3, 2.7 Novel features*.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to multi-hull craft of composite construction as defined in *Ch 1, 1 Background*.

1.2 General

1.2.1 Except as otherwise specified within this Chapter, the scantlings and arrangements of multi-hull craft are to be determined in accordance with the procedures described in, or as required by *Pt 8, Ch 3 Scantling Determination for Mono-Hull Craft* for mono-hull craft, using the pressures from *Pt 5 Design and Load Criteria* appropriate to multi-hull craft.

1.3 Direct calculations

1.3.1 Where the craft is of unusual design, form or proportions, or where the speed of the craft exceeds 60 knots the scantlings are to be determined by direct calculation.

1.3.2 The requirements of this Chapter may be modified where direct calculation procedures are adopted to analyse the stress distribution in the primary structure.

1.4 Equivalents

1.4.1 Lloyd's Register (hereinafter referred to as 'LR') will consider direct calculations for the derivation of scantlings as an alternative and equivalent to those derived by Rule requirements in accordance with *Pt 3, Ch 1, 2 Direct calculations*.

1.5 Symbols and definitions

1.5.1 Unless otherwise specified the symbols and definitions for use within this Chapter are as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions*.

1.5.2 **Bottom outboard.** For high speed craft, where the scantlings of the bottom shell are governed by impact pressure considerations, the bottom outboard shell is defined as the area of the hull between the outboard edge of the keel and the outer bilge tangential point. For displacement and semi displacement type craft where the scantlings of the bottom shell are governed by either hydrostatic or pitching pressures, the bottom outboard shell is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

1.5.3 **Bottom inboard.** For high speed craft, where the scantlings of the bottom shell are governed by impact pressure considerations, the bottom inboard shell is defined as the area of the hull between the inboard edge of the keel and the inner bilge tangential point. For displacement and semi displacement type craft where the scantlings of the bottom shell are governed by

either hydrostatic or pitching pressures the bottom inboard shell is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

1.5.4 **Cross-deck.** The cross-deck is defined as the structure which forms the bridge connection between any two adjacent hulls.

1.5.5 **Haunch.** The haunch is defined as the transition area between the cross-deck and the side inboard shell laminate.

1.5.6 **Side inboard.** The side inboard is defined as the area between the bottom inboard shell and the wet-deck (or lower edge of the haunches, where fitted).

1.5.7 **Side outboard.** The side outboard is defined as the area between bottom outboard shell and the deck at side.

1.5.8 **Wet-deck.** The wet-deck is defined as the area between the upper edges of the side inboard laminate (or upper edges of the haunches, where fitted).

■ *Section 2* Minimum thickness requirements

2.1 General

2.1.1 The minimum thickness requirements for single skin laminates are to be in accordance with *Pt 8, Ch 3, 2 Minimum thickness requirements*.

2.1.2 The minimum amount of reinforcement in single skin laminates which form the skins of sandwich laminate is to be in accordance with *Pt 8, Ch 3, 2 Minimum thickness requirements*. In addition, the minimum amount of reinforcement requirements of *Table 4.2.1 Minimum amount of reinforcement in sandwich laminate skins* are to be complied with. The amount of reinforcement is to be corrected for craft type, craft length and fibre content in accordance with *Pt 8, Ch 3, 2.5 Minimum skin reinforcement in sandwich laminates*.

Table 4.2.1 Minimum amount of reinforcement in sandwich laminate skins

Panel location	Minimum amount of reinforcement, W_{min} (g/m^2)		Sandwich skin length factor, f_{LS}
	Glass	Carbon/Aramid	
Bottom outboard, outer skin	3650	2700	0,33
Bottom outboard, inner skin	2850	2100	0,33
Side outboard, outer skin	3250	2400	0,33
Side outboard, inner skin	2450	1950	0,33
Wet-deck, outer skin	3250	2400	0,33
Wet-deck, inner skin	2450	1950	0,33
Cross-deck, outer skin	2450	1950	0,33
Cross-deck, inner skin	1650	1300	0,0
Note The minimum amount of reinforcement in hybrid laminates will be individually considered on an equivalence basis. *See Pt 8, Ch 3, 2.9 Sheathing 2.9.2*.			

2.1.3 In addition, where laminates contribute to the global strength of the craft, the thickness is to be not less than that required to satisfy global strength requirements.

Section 3
Shell envelope laminate

3.1 General

3.1.1 Except as otherwise specified within this Section, the scantlings and arrangements for the shell envelope laminate are to be determined in accordance with the procedures described in, or as required by *Pt 8, Ch 3, 3 Shell envelope laminate* for mono-hull craft, using the pressures from *Pt 5 Design and Load Criteria* appropriate to multi-hull craft.

3.2 Keel plates

3.2.1 The breadth, b_K, and thickness, t_K, of plate keels are not to be taken as less than:

$$b_K = 5,0 L_R + 250 \text{ mm}$$

$$t_K = \sqrt{k_t}\left(5,0 L^{\ 0,45}{}_R\right) \text{ mm}$$

where

L_R = Rule length, in metres, as defined in *Pt 3, Ch 2, 6.1 General*

k_t is as defined in *Pt 8, Ch 3, 2.1 General*.

3.2.2 In no case is the thickness of the keel to be less than that of the adjacent bottom shell laminate.

3.2.3 The width and thickness of plate keels are to be maintained throughout the length of the craft from the transom to a point not less than 25 per cent of the freeboard measured at the forward perpendicular (FP) above the deepest load waterline on the stem. Thereafter the keel thickness may be reduced to that required by *Pt 8, Ch 3, 3.3 Stem plate 3.3.1* for the stem. Laminate tapers are to comply with *Pt 8, Ch 3, 3.14 Local reinforcement 3.14.2*.

3.2.4 Where the bottom shell is of sandwich construction the keel is to be formed by locally returning to single skin construction for a width as required by *Pt 8, Ch 4, 3.2 Keel plates 3.2.1*. The Rule thickness of keel is to comprise both the inner and outer skins of the adjacent bottom shell sandwich plus additional reinforcement as required. The distribution of reinforcement in way of the plate keel and sandwich bottom structure is to be in accordance with *Figure 4.3.1 Single skin/Sandwich skin intersection detail*. *See also Pt 8, Ch 3, 3.2 Keel plate 3.2.4*.

3.2.5 For large, novel, asymmetric hull form craft, or yachts with externally attached ballast keels, or where it is proposed to incorporate keels of the `bar' type the scantlings of the keel will be specially considered.

3.3 Bottom outboard

3.3.1 For all craft types, the minimum bottom outboard shell laminate thickness as required by the Rules is to be extended over the region as defined in *Pt 8, Ch 4, 1.5 Symbols and definitions 1.5.2* for displacement and semi-displacement craft.

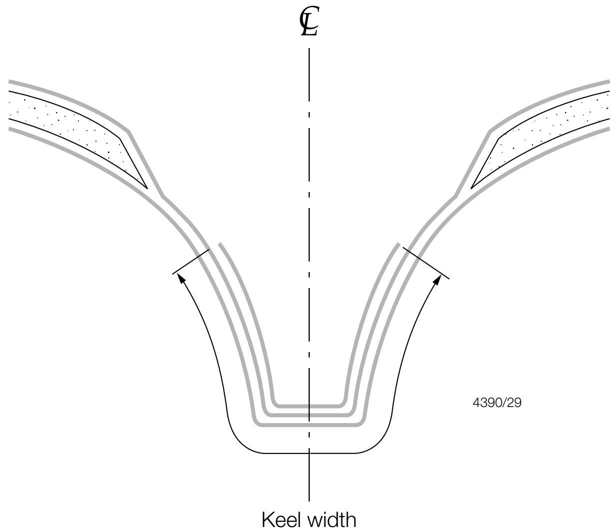


Figure 4.3.1 Single skin/Sandwich skin intersection detail

3.3.2 The bending moment assumed to be carried by the bottom outboard shell laminate is to be not less than that determined by *Pt 8, Ch 3, 1.9 Plate and sandwich laminates 1.9.1*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by *Pt 8, Ch 4, 3.3 Bottom outboard 3.3.3* and *Pt 8, Ch 4, 3.3 Bottom outboard 3.3.5* respectively.

3.3.3 An estimate of the thickness of **bottom outboard single skin laminate** is to be determined from *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.1*. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.3* and *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.4*, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* are to be complied with.

3.3.4 In no case is the minimum thickness of single skin laminate to be taken as less than 5,5 mm.

3.3.5 An estimate of the stiffness $E\,I$, the thickness of single skin laminate for outer and inner skins of the **bottom outboard sandwich panel** and the thickness of core material is to be determined from *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.2* and *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.9* respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.7* and *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.8*. The allowable tensile and compressive stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* are to be complied with.

3.3.6 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of *Pt 8, Ch 4, 2.1 General 2.1.2*.

3.3.7 Special consideration may be given to laminate thicknesses lesser than those required by *Pt 8, Ch 4, 3.3 Bottom outboard 3.3.4* and *Pt 8, Ch 4, 3.3 Bottom outboard 3.3.6*, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see Pt 8, Ch 3, 2.3 Sandwich skin laminate 2.3.1*, and the equivalent impact resistance is demonstrated as required by *Pt 8, Ch 3, 2.8 Impact considerations 2.8.2*.

3.4 Bottom inboard

3.4.1 The scantlings and arrangements for bottom inboard shell laminate are to be determined in accordance with the procedures described in *Pt 8, Ch 4, 3.3 Bottom outboard* using the bottom inboard shell design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

3.5 Side outboard

3.5.1 The side outboard shell is as defined in *Pt 8, Ch 4, 1.5 Symbols and definitions 1.5.7*.

3.5.2 For all craft types, the minimum side outboard shell laminate thickness as required by the Rules is to be extended over the region as defined in *Pt 8, Ch 4, 3.5 Side outboard 3.5.1* for displacement and semi-displacement craft.

3.5.3 The bending moment assumed to be carried by the side outboard shell laminate is to be not less than that determined by *Pt 8, Ch 3, 1.9 Plate and sandwich laminates 1.9.1*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by *Pt 8, Ch 4, 3.5 Side outboard 3.5.4* and *Pt 8, Ch 4, 3.5 Side outboard 3.5.6* respectively.

3.5.4 An estimate of the thickness of **side outboard single skin laminate** is to be determined from *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.1*. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.3* and *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.4*, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* are to be complied with.

3.5.5 In no case is the minimum thickness of single skin laminate to be taken as less than 5 mm.

3.5.6 An estimate of the stiffness $E\,I$, the thickness of single skin laminate for outer and inner skins of the **side outboard sandwich panel** and the thickness of core material is to be determined from *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.2* and *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.9* respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.7* and *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.8*. The allowable tensile and compressive stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* are to be complied with.

3.5.7 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of *Pt 8, Ch 4, 2.1 General 2.1.2*.

3.5.8 Special consideration may be given to laminate thicknesses lesser than those required by *Pt 8, Ch 4, 3.5 Side outboard 3.5.5* and *Pt 8, Ch 4, 3.5 Side outboard 3.5.7*, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see Pt 8, Ch 3, 2.3 Sandwich skin laminate 2.3.1*, and the equivalent impact resistance is demonstrated as required by *Pt 8, Ch 3, 2.8 Impact considerations 2.8.2*.

3.6 Side inboard

3.6.1 The scantlings and arrangements for side inboard shell laminate are to be determined in accordance with the procedures described in *Pt 8, Ch 4, 3.3 Bottom outboard* using the side inboard shell design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate.

3.7 Wet-deck

3.7.1 The wet-deck is as defined in *Pt 8, Ch 4, 1.5 Symbols and definitions 1.5.8*.

3.7.2 The bending moment assumed to be carried by the wet-deck laminate is to be not less than that determined by *Pt 8, Ch 3, 1.9 Plate and sandwich laminates 1.9.1*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by *Pt 8, Ch 4, 3.7 Wet-deck 3.7.3* and *Pt 8, Ch 4, 3.7 Wet-deck 3.7.5* respectively.

3.7.3 An estimate of the thickness of wet-deck single skin laminate is to be determined from *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.1*. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.3* and *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.4*, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* are to be complied with.

3.7.4 In no case is the minimum thickness of single skin laminate to be taken as less than 5 mm.

3.7.5 An estimate of the $E\,I$, the thickness of single skin laminate for outer and inner skins of the wet-deck sandwich panel and the thickness of core material is to be determined from *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.2* and *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.9* respectively. The tensile and compressive stresses are to be

determined for each ply of reinforcement in the proposed laminate using *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.7* and *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.8*. The allowable tensile and compressive stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* are to be complied with.

3.7.6 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of *Pt 8, Ch 4, 2.1 General 2.1.2*.

3.7.7 Special consideration may be given to laminate thicknesses lesser than those required by *Pt 8, Ch 4, 3.7 Wet-deck 3.7.4* and *Pt 8, Ch 4, 3.7 Wet-deck 3.7.6*, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see Pt 8, Ch 3, 2.3 Sandwich skin laminate 2.3.1*, and the equivalent impact resistance is demonstrated as required by *Pt 8, Ch 3, 2.8 Impact considerations 2.8.2*.

3.7.8 The wet-deck laminate on the underside of the cross-deck structure may require to be additionally protected, particularly where the air gap is small and there is a high risk of localised impact due to collision with floating debris, ice, etc. in the service area. In such cases the requirements for sheathing, given in *Pt 8, Ch 3, 2.9 Sheathing*, are to be complied with.

3.8 Transom

3.8.1 The scantlings and arrangements of transoms are to be not less than as required for the adjacent bottom inboard or side outboard structure as appropriate.

3.8.2 Where water jet or sterndrive units are fitted, the scantlings of the plating in way of the nozzles and connections will be specially considered.

3.9 Haunch reinforcement (SWATH)

3.9.1 For craft above 30 m in length, L_R, the stresses in the haunch area are to be derived using a two dimensional fine mesh finite element analysis. The model is to extend horizontally into the box structure and vertically into the strut structure. All discontinuities and cut-outs are to be modelled in order to determine shear stresses at critical locations and stresses for the determination of fatigue strength.

3.9.2 Due consideration is to be given to shear lag when calculating the effective breadth of the attached laminate.

3.10 Lower hull (SWATH)

3.10.1 Where the lower hull structure incorporates ring frames and attached shell laminate fitted between bulkheads or diaphragms, the thickness of the lower hull shell laminate may be derived from an established method for shell analysis or recognised standard for pressure vessels. Modes of failure to be considered are buckling, frame collapse, inter frame shell collapse and overall frame shell collapse between bulkheads. Copies of direct calculations are to be submitted for consideration.

3.10.2 In general the design load to be used is the pressure load given in *Pt 5, Ch 4, 3.1 Hull structures*. If other loads are considered to be of significance for the scantling determination these are to be taken into account.

3.11 Novel features

3.11.1 Where the Rules do not specifically define the requirements for laminate elements with novel features then the scantlings and arrangements are to be determined by direct calculations. Such calculations are to be carried out on the basis of the Rules, recognised standards and good practice, and are to be submitted for consideration.

■ *Section 4* Shell envelope framing

4.1 General

4.1.1 Except as otherwise specified within this Section, the scantlings and arrangements for shell envelope framing are to be determined in accordance with the procedures described in, or as required by *Pt 8, Ch 3, 4 Shell envelope framing* for mono-hull craft, using the pressures from *Pt 5 Design and Load Criteria* appropriate to multi-hull craft.

4.1.2 The requirements in this Section apply to longitudinally and transversely framed shell envelopes.

4.2 Bottom outboard longitudinal stiffeners

4.2.1 The bottom outboard longitudinal stiffeners are to be supported by bottom transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.2.2 Bottom outboard longitudinal stiffeners are to be continuous through the supporting structures.

4.2.3 Where it is impracticable to comply with the requirements of *Pt 8, Ch 4, 4.2 Bottom outboard longitudinal stiffeners 4.2.2*, or where it is desired to terminate the bottom outboard longitudinal stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.2.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate, and the coefficients Φ_M, Φ_S and Φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* in Chapter 3 for the load model (b).

4.2.5 The allowable tensile, compressive and shear stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* in Chapter 7, and the span/deflection ratios indicated in *Table 7.2.1 Limiting span/deflection ratio* in Chapter 7 are to be complied with.

4.3 Bottom outboard longitudinal primary stiffeners

4.3.1 The bottom outboard longitudinal primary stiffeners are to be supported by bottom transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 6 m apart.

4.3.2 Bottom outboard longitudinal primary stiffeners are to be continuous through the supporting structures.

4.3.3 Where it is impracticable to comply with the requirements of *Pt 8, Ch 4, 4.3 Bottom outboard longitudinal primary stiffeners 4.3.2*, or where it is desired to terminate the bottom outboard longitudinal primary stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.3.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate, and the coefficients Φ_M, Φ_S and Φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* in Chapter 3 for the load model (a).

4.3.5 The allowable tensile, compressive and shear stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* in Chapter 7, and the span/deflection ratios indicated in *Table 7.2.1 Limiting span/deflection ratio* in Chapter 7 are to be complied with.

4.4 Bottom outboard transverse stiffeners

4.4.1 Bottom outboard transverse stiffeners are defined as local stiffening members which support the bottom shell, and which may be continuous or intercostal.

4.4.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for high speed or displacement type craft as appropriate, and the coefficients Φ_M, Φ_S and Φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* in Chapter 3 for the load model (b).

4.4.3 The allowable tensile, compressive and shear stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* in Chapter 7, and the span/deflection ratios indicated in *Table 7.2.1 Limiting span/deflection ratio* in Chapter 7 are to be complied with.

4.5 Bottom outboard transverse frames

4.5.1 Bottom outboard transverse frames are defined as stiffening members which support the bottom shell. They are to be effectively continuous and be bracketed at their end connections to side frames and bottom floors as appropriate.

4.5.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate, and the coefficients Φ_M, Φ_S and Φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* in Chapter 3 for the load model (a).

4.5.3 The allowable tensile, compressive and shear stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* in Chapter 7, and the span/deflection ratios indicated in *Table 7.2.1 Limiting span/deflection ratio* in Chapter 7 are to be complied with.

4.6 Bottom outboard transverse web frames

4.6.1 Bottom outboard transverse web frames are defined as primary stiffening members which support bottom shell longitudinals. They are to be continuous and be substantially bracketed at their end connections to side web frames and bottom floors.

4.6.2 Where it is impracticable to comply with the requirements of *Pt 8, Ch 4, 4.6 Bottom outboard transverse web frames 4.6.1*, or where it is desired to terminate the bottom inboard transverse web frames in way of bulkheads or integral tank boundaries, etc. all web frames are to be bracketed in way of their end connections, to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be `soft toed' (*see Figure 3.4.1 `Soft-toe'* in Chapter 3) and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.6.3 The Rule requirements for the bending moment, shear force, shear stress and deflection are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate, and the coefficients Φ_M, Φ_S and Φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* in Chapter 3 for the load model (a).

4.6.4 The allowable tensile, compressive and shear stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* in Chapter 7, and the span/deflection ratios indicated in *Table 7.2.1 Limiting span/deflection ratio* in Chapter 7 are to be complied with.

4.7 Bottom inboard longitudinal stiffeners

4.7.1 The scantlings and arrangements for bottom inboard longitudinal stiffeners are to be determined in accordance with the procedures described in *Pt 8, Ch 4, 4.2 Bottom outboard longitudinal stiffeners* using the bottom inboard longitudinal stiffeners design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

4.8 Bottom inboard longitudinal primary stiffeners

4.8.1 The scantlings and arrangements for bottom inboard longitudinal primary stiffeners are to be determined in accordance with the procedures described in *Pt 8, Ch 4, 4.3 Bottom outboard longitudinal primary stiffeners* using the bottom inboard longitudinal primary stiffeners design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

4.9 Bottom inboard transverse stiffeners

4.9.1 The scantlings and arrangements for bottom inboard transverse stiffeners are to be determined in accordance with the procedures described in *Pt 8, Ch 4, 4.4 Bottom outboard transverse stiffeners* using the bottom inboard transverse stiffeners design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

4.10 Bottom inboard transverse frames

4.10.1 The scantlings and arrangements for bottom inboard transverse frames are to be determined in accordance with the procedures described in *Pt 8, Ch 4, 4.5 Bottom outboard transverse frames* using the bottom inboard transverse frames design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

4.11 Bottom inboard transverse web frames

4.11.1 The scantlings and arrangements for bottom inboard transverse web frames are to be determined in accordance with the procedures described in *Pt 8, Ch 4, 4.6 Bottom outboard transverse web frames* using the bottom inboard transverse web frames design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

4.12 Side outboard longitudinal stiffeners

4.12.1 The side outboard longitudinal stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.12.2 Side outboard longitudinal stiffeners are to be continuous through the supporting structures.

4.12.3 Where it is impracticable to comply with the requirements of *Pt 8, Ch 4, 4.12 Side outboard longitudinal stiffeners 4.12.2*, or where it is desired to terminate the side outboard longitudinal stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.12.4 The Rule requirements for the bending moment, shear force, shear stress and deflection are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate, and the coefficients Φ_M, Φ_S and Φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* in Chapter 3 for the load model (b).

4.12.5 The allowable tensile, compressive and shear stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* in Chapter 7, and the span/deflection ratios indicated in *Table 7.2.1 Limiting span/deflection ratio* in Chapter 7 are to be complied with.

4.13 Side outboard longitudinal primary stiffeners

4.13.1 The side outboard longitudinal primary stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 6 m apart.

4.13.2 Side outboard longitudinal primary stiffeners are to be continuous through the supporting structures.

4.13.3 Where it is impracticable to comply with the requirements of *Pt 8, Ch 4, 4.13 Side outboard longitudinal primary stiffeners 4.13.2*, or where it is desired to terminate the side outboard longitudinal primary stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.13.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate, and the coefficients Φ_M, Φ_S and Φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* in Chapter 3 for the load model (a).

4.13.5 The allowable tensile, compressive and shear stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* in Chapter 7, and the span/deflection ratios indicated in *Table 7.2.1 Limiting span/deflection ratio* in Chapter 7 are to be complied with.

4.14 Side outboard transverse stiffeners

4.14.1 Side outboard transverse stiffeners are defined as local stiffening members which support the side shell, and which may be continuous or intercostal.

4.14.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate, and the coefficients Φ_M, Φ_S and Φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* in Chapter 3 for the load model (b).

4.14.3 The allowable tensile, compressive and shear stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* in Chapter 7, and the span/deflection ratios indicated in *Table 7.2.1 Limiting span/deflection ratio* in Chapter 7 are to be complied with.

4.15 Side outboard transverse frames

4.15.1 Side outboard transverse frames are defined as stiffening members supporting the side shell and spanning continuously between bottom floors/frames and decks. They are to be effectively constrained against rotation at their end connections.

4.15.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate, and the coefficients Φ_M, Φ_S and Φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* in Chapter 3 for the load model (a).

4.15.3 The allowable tensile, compressive and shear stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* in Chapter 7, and the span/deflection ratios indicated in *Table 7.2.1 Limiting span/deflection ratio* in Chapter 7 are to be complied with.

4.16 Side outboard transverse web frames

4.16.1 Side outboard transverse web frames are defined as primary stiffening members which support side shell longitudinals, they are to be continuous and be substantially bracketed at their end connections to side web frames and side floors.

4.16.2 Where it is impracticable to comply with the requirements of *Pt 8, Ch 4, 4.16 Side outboard transverse web frames 4.16.1*, or where it is desired to terminate the side outboard transverse web frames in way of bulkheads or integral tank boundaries, etc. all web frames are to be bracketed in way of their end connections, to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be `soft toed' *see Figure 3.4.1 `Soft-toe'* in Chapter 3, and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.16.3 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate, and the coefficients Φ_M, Φ_S and Φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* in Chapter 3 for the load model (a).

4.16.4 The allowable tensile, compressive and shear stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* in Chapter 7, and the span/deflection ratios indicated in *Table 7.2.1 Limiting span/deflection ratio* in Chapter 7 are to be complied with.

4.17 Side inboard longitudinal stiffeners

4.17.1 The scantlings and arrangements for side inboard longitudinal stiffeners are to be determined in accordance with the procedures described in *Pt 8, Ch 4, 4.12 Side outboard longitudinal stiffeners* using the side inboard longitudinal stiffeners design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

4.18 Side inboard longitudinal primary stiffeners

4.18.1 The scantlings and arrangements for side inboard longitudinal primary stiffeners are to be determined in accordance with the procedures described in *Pt 8, Ch 4, 4.8 Bottom inboard longitudinal primary stiffeners* using the side inboard longitudinal primary stiffeners design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

4.19 Side inboard transverse stiffeners

4.19.1 The scantlings and arrangements for side inboard transverse stiffeners are to be determined in accordance with the procedures described in *Pt 8, Ch 4, 4.14 Side outboard transverse stiffeners* using the side inboard transverse stiffeners design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

4.20 Side inboard transverse frames

4.20.1 The scantlings and arrangements for side inboard transverse frames are to be determined in accordance with the procedures described in *Pt 8, Ch 4, 4.15 Side outboard transverse frames* using the side inboard transverse frames design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

4.21 Side inboard transverse web frames

4.21.1 The scantlings and arrangements for side inboard transverse web frames are to be determined in accordance with the procedures described in *Pt 8, Ch 4, 4.16 Side outboard transverse web frames* using the side inboard transverse web frames design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate.

4.22 Wet-deck longitudinal stiffeners

4.22.1 The wet-deck longitudinal stiffeners are to be supported by transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.22.2 Wet-deck longitudinal stiffeners are to be continuous through the supporting structures.

4.22.3 Where it is impracticable to comply with the requirements of *Pt 8, Ch 4, 4.22 Wet-deck longitudinal stiffeners 4.22.2*, or where it is desired to terminate the wet-deck longitudinal stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.22.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate, and the coefficients Φ_M, Φ_S and Φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* in Chapter 3 for the load model (b).

4.22.5 The allowable tensile, compressive and shear stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* in Chapter 7, and the span/deflection ratios indicated in *Table 7.2.1 Limiting span/deflection ratio* in Chapter 7 are to be complied with.

4.22.6 In no case are the scantlings and arrangements for the wet-deck longitudinal stiffeners to be taken less than as required for the side inboard longitudinal stiffeners indicated in *Pt 8, Ch 4, 4.17 Side inboard longitudinal stiffeners*.

4.23 Wet-deck longitudinal primary stiffeners

4.23.1 The wet-deck longitudinal primary stiffeners are to be supported by transverse web frames, bulkheads, or other primary structure, generally spaced not more than 6 m apart.

4.23.2 Wet-deck longitudinal primary stiffeners are to be continuous through the supporting structures.

4.23.3 Where it is impracticable to comply with the requirements of *Pt 8, Ch 4, 4.23 Wet-deck longitudinal primary stiffeners 4.23.2*, or where it is desired to terminate the wet-deck longitudinal primary stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.23.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate, and the coefficients Φ_M, Φ_S and Φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* in Chapter 3 for the load model (a).

4.23.5 The allowable tensile, compressive and shear stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* in Chapter 7, and the span/deflection ratios indicated in *Table 7.2.1 Limiting span/deflection ratio* in Chapter 7 are to be complied with.

4.23.6 In no case are the scantlings and arrangements for the wet-deck longitudinal primary stiffeners to be taken less than as required for the side inboard longitudinal primary stiffeners indicated in *Pt 8, Ch 4, 4.18 Side inboard longitudinal primary stiffeners*.

4.23.7 Additionally the requirements of *Pt 8, Ch 6 Hull Girder Strength*, in respect of global strength are to be complied with.

4.24 Wet-deck transverse stiffeners

4.24.1 Wet-deck transverse stiffeners are defined as local stiffening members which support the wet-deck shell, and which may be continuous or intercostal.

4.24.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate, and the coefficients Φ_M, Φ_S and Φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* in Chapter 3 for the load model (b).

4.24.3 The allowable tensile, compressive and shear stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* in Chapter 7, and the span/deflection ratios indicated in *Table 7.2.1 Limiting span/deflection ratio* in Chapter 7 are to be complied with.

4.24.4 In no case are the scantlings and arrangements for the wet-deck transverse stiffeners to be taken less than as required for the side inboard transverse stiffeners indicated in *Pt 8, Ch 4, 4.19 Side inboard transverse stiffeners*.

4.25 Wet-deck transverse frames

4.25.1 Wet-deck transverse frames are defined as stiffening members which support the wet-deck shell, they are to be effectively continuous and be bracketed at their end connections to side frames and side floors as appropriate.

4.25.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate, and the coefficients Φ_M, Φ_S and Φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* in Chapter 3 for the load model (a).

4.25.3 The allowable tensile, compressive and shear stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* in Chapter 7, and the span/deflection ratios indicated in *Table 7.2.1 Limiting span/deflection ratio* in Chapter 7 are to be complied with.

4.25.4 In no case are the scantlings and arrangements for the wet-deck transverse frames to be taken less than as required for the side inboard transverse frames indicated in *Pt 8, Ch 4, 4.20 Side inboard transverse frames*.

4.26 Wet-deck transverse web frames

4.26.1 Wet-deck transverse web frames are defined as primary stiffening members which support wet-deck longitudinals. They are to be continuous and be substantially bracketed at their end connections to side web frames and side floors.

4.26.2 Where it is impracticable to comply with the requirements of *Pt 8, Ch 4, 4.26 Wet-deck transverse web frames 4.26.1*, or where it is desired to terminate the wet-deck transverse web frames in way of bulkheads or integral tank boundaries, etc. all web frames are to be bracketed in way of their end connections, to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed', *see Figure 3.4.1 `Soft-toe'* in Chapter 3, and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.26.3 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate, and the coefficients Φ_M, Φ_S and Φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* in Chapter 3 for the load model (a).

4.26.4 The allowable tensile, compressive and shear stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* in Chapter 7, and the span/deflection ratios indicated in *Table 7.2.1 Limiting span/deflection ratio* in Chapter 7 are to be complied with.

4.26.5 In no case are the scantlings and arrangements for the wet-deck transverse web frames to be taken less than as required for the side inboard transverse web frames indicated in *Pt 8, Ch 4, 4.21 Side inboard transverse web frames*.

4.26.6 Primary transverse web frame members which link the strength deck to the wet-deck structure and which carry the transverse global loading, are additionally to comply with *Pt 8, Ch 6, 3.4 Torsional strength*.

4.26.7 Particular care is to be taken to ensure that the continuity of transverse structural strength is maintained. All primary transverse members are to be continuous through the side inboard structure and be integrated into transverse bulkheads or other primary structure within each hull, *see Figure 4.4.1 End connection detail, wet-deck structure*. In the case of trimaran type craft the primary transverse members are to be continuous through the centre hull. Additionally the side inboard shell laminate in way of the intersection is to be locally increased in thickness by not less than 50 per cent. Copies of direct calculations are to be submitted for consideration.

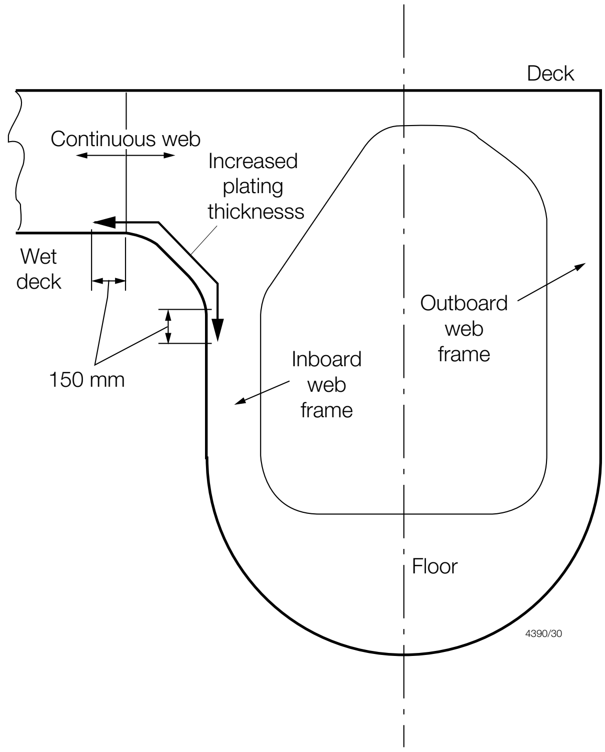


Figure 4.4.1 End connection detail, wet-deck structure

4.27 Novel features

4.27.1 Where the Rules do not specifically define the requirements for novel features then the scantlings and arrangements are to be determined by direct calculations. Such calculations are to be carried out on the basis of the Rules, recognised standards and good practice, and are to be submitted for consideration.

■ *Section 5*
Single bottom structure and appendages

5.1 General

5.1.1 Except as otherwise specified within this Section, the scantlings and arrangements for single bottom structure and appendages are to be determined in accordance with the procedures described in, or as required by *Pt 8, Ch 3, 5 Single bottom structure and appendages* for mono-hull craft, using the pressures from *Pt 5 Design and Load Criteria* appropriate to multi-hull craft.

5.1.2 The minimum thickness requirements detailed in *Pt 8, Ch 4, 2.1 General* are to be complied with as appropriate.

5.2 Keel

5.2.1 The scantlings and arrangements of plate keels are to be in accordance with *Pt 8, Ch 4, 3.2 Keel plates*. Where it is proposed to incorporate keels of the bar type such arrangements would require to be specially considered.

5.3 Centre girder

5.3.1 Centreline girders are to be fitted throughout the length of each hull and are generally to be fitted in association with transverse frames, transverses supporting longitudinals or where the breadth of floors at the upper edge is greater than 1,5 m.

5.3.2 Centreline girders may be formed with intercostal or continuous top hat or plate webs. Where girder webs are intercostal, additional bracketing and local reinforcement as given in *Pt 8, Ch 3, 3.14 Local reinforcement* are to be provided to maintain the continuity of structural strength. The face reinforcement in all cases is to be continuous.

5.3.3 The web depth of the centre girder in general is to be equal to the depth of the floors at the centreline as specified in *Pt 8, Ch 4, 5.5 Floors*.

5.3.4 The web thickness, t_w, for a centre girder of `top- hat' type section is to be not less than that required by *Pt 8, Ch 3, 1.17 Stiffener proportions*, or as determined as follows whichever is the greater and in no case is t_w to be taken less than 5,0 mm:

$$t_w = \sqrt{k_A}\left(\sqrt{L_R} + 1,37\right) \text{ mm}$$

where k_A and L_R are as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*.

5.3.5 The web thickness for a centre girder of single plate laminate construction is to be two times the thickness as required by *Pt 8, Ch 4, 5.3 Centre girder 5.3.4*.

5.3.6 The face area of the centre girder, A_f, is to be not less than:

$$A_f = 1,18 L_R k_A \text{ cm}^2$$

where

$k_A = \dfrac{85}{\sigma_u}$

σ_u = ultimate tensile strength of the face area laminate, in N/mm^2

L_R = as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*

5.3.7 The face area of the centre girder outside 0,5L_R about midships may be reduced to 80 per cent of the value given in *Pt 8, Ch 4, 5.3 Centre girder 5.3.6*.

5.3.8 The face thickness, t_f, is to be not less than the web thickness of the centre girder.

5.3.9 Additionally, the requirements of *Pt 8, Ch 4, 4.8 Bottom inboard longitudinal primary stiffeners* for bottom longitudinal primary stiffeners are to be complied with.

5.4 Side girder

5.4.1 Where the floor breadth at the upper edge exceeds 4,0 m side girders are to be fitted at each side of the centre girder such that the spacing between the side and centre girders or between the side girders themselves is not greater than 3 m. Side girders where fitted are to extend as far forward and aft as practicable and are in general to terminate in way of bulkheads, deep floors or other primary transverse structure.

5.4.2 In the engine room, additional side girders are generally to be fitted in way of the main machinery.

5.4.3 The face area of side girders, A_f, is not to be taken as less than:

$$A_f = 0,82 L_R k_A \text{ cm}^2$$

where k_A and L_R are as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*.

5.4.4 The web thickness, t_w, for side girders of 'top-hat' type section is to be not less than as required by *Pt 8, Ch 3, 1.17 Stiffener proportions* or as determined as follows whichever is the greater and in no case is t_w to be taken less than 5,0 mm:

$$t_w = \sqrt{0,66 k_A L_R} \text{ mm}$$

where k_A and L_R are as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*.

5.4.5 The web thickness for side girders of single plate laminate construction is to be two times the thickness as required by *Pt 8, Ch 4, 5.4 Side girder 5.4.4*.

5.4.6 Additionally, the requirements of *Pt 8, Ch 4, 4.8 Bottom inboard longitudinal primary stiffeners* for bottom longitudinal primary stiffeners are to be complied with.

5.4.7 Watertight side girders, or side girders forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deeptanks as detailed in *Pt 8, Ch 3, 7.3 Watertight bulkheads* and *Pt 8, Ch 3, 7.4 Deep tanks* respectively.

5.5 Floors

5.5.1 In transversely framed craft, floors are generally to be fitted at every frame and underneath each bulkhead.

5.5.2 In longitudinally framed craft, floors are to be fitted at every transverse web frame and bulkhead and generally at a spacing not exceeding 2 m. Additional transverse floors or webs are to be fitted at half web-frame spacing in way of engine seatings and thrust bearings, pillars, skegs, ballast/bilge keels and the bottom of the craft in the forefoot region.

5.5.3 The overall depth of transverse floors at the centreline, d_W, is not to be taken as less than:

$$d_W = 6,2L_R + 50 \text{ mm}$$

5.5.4 The web thickness, t_w, for transverse floors of `top-hat' type section is to be not less than as required by *Pt 8, Ch 3, 1.17 Stiffener proportions*, or as determined as follows whichever is the greater and in no case is t_w to be taken less than 5,0 mm:

$$t_w = \sqrt{k_A}\left(\frac{4,33d_W}{1000} + 2,75\right)\left(\frac{s}{1000} + 0,5\right) \text{ mm}$$

where

d_W = as defined in *Pt 8, Ch 4, 5.5 Floors 5.5.3*

k_A and s are as defined in *Pt 8, Ch 4, 5.3 Centre girder 5.3.6*.

5.5.5 The web thickness for transverse floors of single plate laminate construction is to be two times the thickness as required by *Pt 8, Ch 4, 5.5 Floors 5.5.4*.

5.5.6 If the side frames of the craft are attached to the floors by brackets, the depth of floor may be reduced by 15 per cent and the floor thickness determined using the reduced depth. The brackets are to have the same thickness as the floors, and their arm lengths clear of the frame are to be the same as the reduced floor depth given above.

5.5.7 The face area of floors, A_f, is not to be taken as less than:

$$A_f = 0,82L_R k_A \text{ cm}^2$$

where k_A and L_R are as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*.

5.5.8 The thickness of the face laminate, t_f, is to be not less than the web thickness.

5.5.9 In addition, the requirements of *Pt 8, Ch 4, 4.11 Bottom inboard transverse web frames* for bottom inboard transverse web frames are to be complied with.

5.5.10 Floors are generally to be continuous from side to side.

5.5.11 The tops of floors, in general, may be level from side to side. However, in craft having considerable rise of floor the depth of the floor plate may require to be increased to maintain the required mechanical properties of the section.

5.5.12 The floors in the aft peak are to extend over and provide efficient support to the stern tube(s) where applicable.

5.5.13 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deeptanks as detailed in *Pt 8, Ch 3, 7.3 Watertight bulkheads* or *Pt 8, Ch 3, 7.4 Deep tanks* respectively.

5.6 Floors in machinery space

5.6.1 The depth and mechanical properties of floors between engine or gearbox girders is to be not less than that required to maintain continuity of structural integrity or 50 per cent of the depth given in *Pt 8, Ch 4, 5.5 Floors 5.5.3*. The web thickness and face reinforcement weight of such reduced height floors are to be increased appropriately in order to maintain the continuity of structural strength.

5.7 Lower hull (SWATH)

5.7.1 Where the lower hull structure incorporates ring frames and attached shell laminate fitted between bulkheads or diaphragms, the scantlings of the lower hull shell stiffening may be derived from an established method for stiffening analysis or recognised standard for pressure vessels. Modes of failure to be considered are buckling, frame collapse, inter frame shell collapse and overall frame shell collapse between bulkheads. Copies of detailed calculations are to be submitted for consideration.

5.7.2 In general, the design load used is to be the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement craft as appropriate. If other loads are considered to be of significance for the scantling determination these are to be taken into account.

5.8 Forefoot and stem

5.8.1 The scantlings and arrangements for the forefoot and stem construction are to be in accordance with *Pt 8, Ch 3, 5.11 Forefoot and stem*.

5.9 Transom knee

5.9.1 Transom knees are to be fitted in each hull as necessary in accordance with *Pt 8, Ch 3, 5.12 Transom knee*.

■ *Section 6* Double bottom structure

6.1 General

6.1.1 Except as otherwise specified within this Section, the scantlings and arrangements for double bottom structure are to be determined in accordance with the procedures described in, or as required by *Pt 8, Ch 3, 6 Double bottom structure* for mono-hull craft, using the pressures from *Pt 5 Design and Load Criteria* appropriate to multi-hull craft.

6.1.2 The minimum thickness requirements detailed in *Pt 8, Ch 3, 2.1 General* are to be complied with as appropriate.

6.2 Keel

6.2.1 The breadth and thickness of plate keels are to comply with the requirements of *Pt 8, Ch 4, 3.2 Keel plates*.

6.3 Centreline girder

6.3.1 A centreline girder is to be fitted throughout the length of each hull. The web thickness, t_{W}, of centre girders of 'top-hat' type section is to be not less than as required by *Pt 8, Ch 3, 1.17 Stiffener proportions*. or as determined as follows whichever is the greater and in no case is t_{W} to be taken less than 5,0 mm:

$$t_{\mathrm{W}} = \sqrt{k_{\mathrm{A}}}\left(0,073L_{\mathrm{R}} + 3,64\right) \text{ mm within } 0,4L_{\mathrm{R}} \text{ amidships}$$
$$= \sqrt{k_{\mathrm{A}}}\left(0,073L_{\mathrm{R}} + 2,73\right) \text{ mm atends}$$

where k_{A} and L_{R} are as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*.

6.3.2 The web thickness for a centreline girder of single plate laminate construction is to be two times the thickness as required by *Pt 8, Ch 4, 6.3 Centreline girder 6.3.1*.

6.3.3 The overall depth of the centreline girder, d_{DB}, is not to be taken as less than 630 mm and is to be sufficient to give adequate access to all parts of the double bottom.

6.3.4 Additionally, the requirements of *Pt 8, Ch 4, 4.8 Bottom inboard longitudinal primary stiffeners* for bottom inboard longitudinal primary stiffeners are to be complied with.

6.4 Side girders

6.4.1 Where the breadth of the floor at the upper edge, within a single hull, does not exceed 4,0 m, side girders are not required. Vertical stiffeners are to be fitted to the floors on each side of the centreline girder, the number and positions of these stiffeners being dependent on the arrangement of the double bottom structure.

6.4.2 Where the breadth of the floor at the upper edge, within a single hull, exceeds 4,0 m, side girders are to be fitted at each side of the centre girder such that the spacing between the side and centre girders or between the side girders themselves is not greater than 3 m. Side girders, where fitted, are to extend as far forward and aft as practicable and are in general to terminate in way of bulkheads, deep floors or other primary transverse structure.

6.4.3 Under the main engine, girders extending from the bottom to the top plate of the engine seating are to be fitted. The height of the girders is not to be less than the height of the floor. Engine holding-down bolts are to be arranged as near as practicable to the girders and floors. Where this cannot be achieved, bracket floors are to be fitted.

6.4.4 Side girders are to have a minimum web thickness, t_{w}, as required by *Pt 8, Ch 3, 1.17 Stiffener proportions* but not less than as determined as follows whichever is the greater and in no case is t_{w} to be taken less than 5,0 mm:

$$t_{\text{w}} = \sqrt{k_{\text{A}}}\left(0,064L_{\text{R}} + 4,32\right)\ \text{mm}$$

where k_{A} and L_{R} are as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*.

6.4.5 Additionally, the requirements of *Pt 8, Ch 4, 4.8 Bottom inboard longitudinal primary stiffeners* for bottom inboard longitudinal primary stiffeners are to be complied with.

6.5 Plate floors

6.5.1 Plate floors may be of single skin, sandwich skin or `top-hat' type construction, and are to comply with the requirements of *Pt 8, Ch 4, 5.5 Floors* where applicable.

6.5.2 The web thickness, t_{w}, of non-watertight plate floors of 'top-hat' type section is to be not less than as required by *Pt 8, Ch 3, 1.17 Stiffener proportions* or as determined as follows whichever is the greater and in no case is t_{w} to be taken less than 5,0 mm:

$$t_{\text{w}} = \sqrt{k_{\text{A}}}\left(0,036L_{\text{R}} + 4\right)\ \text{mm}$$

where k_{A} and L_{R} are as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*.

6.5.3 The web thickness for transverse floors of single plate laminate construction is to be two times the thickness as required by *Pt 8, Ch 4, 6.5 Plate floors 6.5.2*.

6.5.4 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of *Pt 8, Ch 4, 2.1 General 2.1.2*.

6.5.5 Additionally, the requirements of *Pt 8, Ch 4, 4.11 Bottom inboard transverse web frames* for bottom inboard transverse web frames are to be complied with.

6.5.6 Plate floors are generally to be continuous between the centre girder and the margin plate.

■ *Section 7*
Bulkheads and deep tanks

7.1 General

7.1.1 Except as otherwise specified within this Section, the scantlings and arrangements for bulkheads and deep tanks are to be determined in accordance with the procedures described in, or as required by *Pt 8, Ch 3, 7 Bulkheads and deep tanks* for mono-hull craft, using the pressures from *Pt 5 Design and Load Criteria* appropriate to multi-hull craft.

7.1.2 The scantlings of non-watertight or partial bulkheads are in general to be as required for watertight bulkheads. Non-watertight or partial bulkheads supporting hull framing are to have scantlings equivalent to frames or web frames as appropriate, in the same position.

7.1.3 Sandwich wood bulkheads, plywood bulkheads or other forms of bulkhead construction will be considered on the basis of equivalent strength.

7.2 Longitudinal bulkheads within cross-deck structure

7.2.1 Longitudinal bulkheads are to be fitted within the cross-deck structure to prevent cross flooding and the spread of flame and smoke. The minimum number of such bulkheads is to be two for catamarans and four for trimarans. Quadrimarans and other craft of novel configuration will be specially considered.

7.2.2 The scantlings and arrangements of cross-deck longitudinal bulkheads are to be determined in accordance with the procedures described in *Pt 8, Ch 3, 7.3 Watertight bulkheads* and *Pt 8, Ch 3, 7.4 Deep tanks* for bulkheads in mono-hull craft.

7.2.3 In addition the requirements of *Pt 8, Ch 4, 7.4 Additional strength required for global loadings* in respect of global strength are to be complied with.

7.3 Transverse bulkheads within the cross-deck structure

7.3.1 The scantlings and arrangements of cross-deck transverse bulkheads are to be determined in accordance with the procedures described in *Pt 8, Ch 3, 7.3 Watertight bulkheads* and *Pt 8, Ch 3, 7.4 Deep tanks* for bulkheads in mono-hull craft.

7.3.2 In addition the requirements of *Pt 8, Ch 4, 7.4 Additional strength required for global loadings* in respect of global strength are to be complied with.

7.4 Additional strength required for global loadings

7.4.1 Where transverse bulkheads or deep tank bulkheads within the cross-deck structure are to assist in resisting torsional or bending loads between the hulls, then the watertight/deep tank bulkheads may be required to be additionally stiffened and the laminate or skin thicknesses may require to be increased. For hull girder strength requirements, *see Pt 8, Ch 6, 3 Hull girder strength for multi-hull craft*.

7.4.2 Longitudinal bulkheads within the cross-deck structure that are to assist in maintaining the longitudinal strength of the vessel are to satisfy both bulkhead/deep tank and longitudinal strength requirements. This may require additional stiffening and increase in plate thickness requirements. For hull girder strength requirements, *see Pt 8, Ch 6, 3 Hull girder strength for multi-hull craft*.

7.4.3 Where longitudinal or transverse cross-deck bulkheads/deep tanks are to carry global loads, detailed calculations are to be submitted.

7.4.4 For longitudinal or transverse cross-deck members carrying global loads, consideration is to be given to stiffener arrangement, alignment, and continuity in order to maximise the rigidity and stiffness of the structure, in resisting the torsional/ bending loads. Due consideration is to be given to the wrinkling and buckling of the skins of sandwich plate laminates. Discontinuity of structural bulkheads is to be avoided.

7.5 Access

7.5.1 Access through the cross-deck structure may be permitted, provided that the global strength requirements are satisfied. Cut-outs through the bulkhead are not to exceed 50 per cent of its depth. The edges of cut-out in sandwich panels are to be suitably reinforced while those of single skin construction are to be sealed.

7.5.2 Where the cross-deck structure acts as a watertight bulkhead pipe or cable runs through, the watertight bulkheads are to be fitted with suitable watertight glands.

7.6 Local strength

7.6.1 Bulkheads that form the cross-deck structure are to be suitably strengthened, if necessary, at the ends of deck girders and where subjected to concentrated loads.

7.7 Integral/deep tanks within cross-deck structure

7.7.1 Where the cross-deck structure forms the boundaries of deep tanks, the scantlings of these boundaries are to satisfy both deep tank and global strength requirements. For general and structural requirements for deep tanks, *see Pt 8, Ch 3, 7.4 Deep tanks*. For global considerations of strength, *see Pt 8, Ch 6, 3 Hull girder strength for multi-hull craft*.

■ *Section 8* Deck structures

8.1 General

8.1.1 Except as otherwise specified within this Section, the scantlings and arrangements for deck structures are to be determined in accordance with the procedures described in, or as required by *Pt 8, Ch 3, 8 Deck Structures* for mono-hull craft, using the pressures from *Pt 5 Design and Load Criteria* appropriate to multi-hull craft.

8.1.2 Deck structures are to comply with the minimum thickness requirements of *Pt 8, Ch 4, 2 Minimum thickness requirements*.

8.1.3 Special attention is to be given to the connections of primary transverse beams to hull side web frames in order to provide adequate load distribution and avoid stress concentrations.

8.1.4 Primary stiffening members are to be continuous and substantially bracketed at their end connections to maintain continuity of structural strength.

8.1.5 Secondary stiffening members are to be effectively continuous and bracketed at their end connections as appropriate.

8.1.6 Design loads to be applied for cross-deck scantling calculations are transverse vertical bending moment and shear force, twin hull torsional connecting moment, external pressure load and appropriate internal loads as defined in *Pt 5 Design and Load Criteria*.

8.2 Arrangements

8.2.1 Deck structures are to comply with the longitudinal and transverse global strength requirements given in *Pt 8, Ch 6 Hull Girder Strength*.

8.3 Symbols and definitions

8.3.1 The term `cross-deck' is used in this Section for the bridging deck, connecting two or more hulls, carrying global transverse loads. *See also Pt 8, Ch 4, 1.5 Symbols and definitions 1.5.4*.

8.4 Cross-deck laminate

8.4.1 The bending moment assumed to be carried by the cross-deck laminate is to be not less than that determined by *Pt 8, Ch 3, 1.9 Plate and sandwich laminates 1.9.1*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by *Pt 8, Ch 4, 8.4 Cross-deck laminate 8.4.2* and *Pt 8, Ch 4, 8.4 Cross-deck laminate 8.4.4* respectively.

8.4.2 An estimate of the thickness of **strength/weather deck single skin laminate** is to be determined from *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.1*. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.3* and *Pt 8, Ch 3, 1.13 Determination of properties and stresses for single skin plate laminates 1.13.4*, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* in Chapter 7 are to be complied with.

8.4.3 In no case is the minimum thickness of single skin laminate to be taken as less than 4 mm.

8.4.4 An estimate of the stiffness, $E\,I$, thickness of single skin laminate for outer and inner skins of the **strength/weather deck sandwich panels** and the thickness of core material is to be determined from *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.2* and *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.9* respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.7* and *Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.8*. The allowable tensile and compressive stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* in Chapter 7 are to be complied with.

8.4.5 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of *Pt 8, Ch 4, 2.1 General 2.1.2*.

8.4.6 Special consideration may be given to laminate thicknesses lesser than those required by *Pt 8, Ch 4, 8.4 Cross-deck laminate 8.4.3* and *Pt 8, Ch 4, 8.4 Cross-deck laminate 8.4.5*, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided and the equivalent impact resistance is demonstrated as required by *Pt 8, Ch 3, 2.8 Impact considerations 2.8.2*.

8.4.7 The scantlings of watertight cockpits are to be of equivalent strength to those for the strength/weather deck, *see also Pt 4 Additional Requirements for Yachts*.

8.4.8 It is recommended that working areas of the weather deck have an anti-slip surface.

8.4.9 Where decks are sheathed with wood or other materials, details of the method of attachment are to be submitted, *see also Pt 8, Ch 3, 2.9 Sheathing*.

8.5 Cross-deck stiffening

8.5.1 The Rule requirements for bending moment, shear force, shear stress and deflection for the cross-deck primary stiffeners are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate, and the coefficients φ_M, φ_S and φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* in Chapter 3 for the load model (a).

8.5.2 The Rule requirements for bending moment, shear force, shear stress and deflection for the cross-deck secondary stiffeners are to be determined from the general equations given in *Pt 8, Ch 3, 1.15 Stiffeners general*, using the design pressure from *Pt 5, Ch 3, 3.1 Hull structures* or *Pt 5, Ch 4, 3.1 Hull structures* for non-displacement or displacement type craft as appropriate, and the coefficients φ_M, φ_S and φ_δ as indicated in *Table 3.1.10 Shear force, bending moment and deflection coefficients* in Chapter 3 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.5.3 The allowable tensile, compressive and shear stress limits indicated in *Table 7.3.1 Limiting stress criteria for local loading* , and the span/deflection ratios indicated in *Table 7.2.1 Limiting span/deflection ratio* are to be complied with.

8.5.4 The geometric properties of stiffener sections are to be calculated in accordance with *Pt 8, Ch 3, 1.16 Geometric properties stiffener sections* using an effective width of attached laminate as given in *Pt 8, Ch 3, 1.7 Effective width of attached plating*.

8.5.5 For cases where there may be excessive rotations or deflections at supports or where the lateral pressure distribution is non-uniform, the above scantlings may have to be increased appropriately.

8.5.6 Where stiffeners are subject to concentrated loads such as pillars, the concentrated loads are to be superimposed on the lateral pressure and strength calculations carried out to demonstrate compliance with the deflection and stress criteria given in *Table 7.2.1 Limiting span/deflection ratio* and *Table 7.3.1 Limiting stress criteria for local loading* .

8.5.7 Where the floating frame system is used, the effect of the plating attached to the stiffening members is to be ignored when calculating the required section stiffness, $E\,I$, of the primary stiffening members, i.e. the full stiffness, $E\,I$, is to be provided by the primary stiffening members only.

8.5.8 Openings in the cross-deck for hatches etc. are to comply with the requirements of *Pt 8, Ch 3, 8.12 Deck openings*.

8.6 Novel features

8.6.1 Where the cross-deck structure is of unusual design, form or proportions, the scantlings are to be determined by direct calculation, *see Pt 8, Ch 3, 2.7 Novel features*.

■ *Section 9*
Superstructures, deckhouses, bulwarks and pillars

9.1 General

9.1.1 The scantlings and arrangements for superstructures, deckhouses and bulwarks are to be determined in accordance with the procedures described in, or as required for mono-hull craft indicated in *Pt 8, Ch 3, 9 Superstructures, deckhouses and bulwarks*.

9.1.2 The scantlings and arrangements for pillars are to be determined in accordance with the procedures described in, or as required for mono-hull craft indicated in *Pt 8, Ch 3, 10 Pillars and pillar bulkheads*.

Section

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to both mono-hull and multi-hull craft of composite construction.

1.2 Symbols and definitions

1.2.1 The symbols in this Section are as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1* and in the appropriate sub-Section.

■ *Section 2* Special features

2.1 Water jet propulsion systems - Construction

2.1.1 The requirements for the construction and installation of water jet units apply irrespective of rated power.

2.1.2 Water jet ducts may be fabricated as an integral part of the hull structure, or as a bolted-in unit. In either case, detailed plans indicating dimensions, scantlings and materials of construction of the following are to be submitted in triplicate.

(a) Arrangement of the system including intended method of attachment to the hull and building-in, geometry of tunnel, shell opening, method of stiffening, reinforcement, etc.
(b) Shaft sealing arrangements.
(c) Details of any shafting support or guide vanes used in the water jet system.
(d) Details and arrangements of inspection ports, their closing appliances and sealing arrangement, etc.
(e) Details and arrangements of protection gratings and their attachments.

2.1.3 When submitting the plans requested in *Pt 8, Ch 5, 2.1 Water jet propulsion systems - Construction 2.1.2*, details of the designers' loadings and their positions of application in the hull are to be submitted and are to include maximum applied thrust, moments and tunnel pressures for which approval of the propulsion system is sought.

2.1.4 All materials used in construction are to be manufactured and tested in accordance with the*Rules for the Manufacture, Testing and Certification of Materials, July 2021*.

2.1.5 Aluminium alloys, where used, are to be of suitable marine grades in accordance with the requirements of *Pt 7 Hull Construction in Aluminium*.

2.1.6 Irrespective of the material used, the strength and supporting structure of all tunnels are to be examined by direct calculation procedures which are to be submitted. In no case are the scantlings to be taken as less than the Rule requirements for the surrounding structure. The strength of the hull structure in way of tunnels is to be maintained. The structure is to be adequately reinforced and compensated as necessary. All openings are to be suitably reinforced and have radiused corners.

2.1.7 Consideration is to be given to providing the inlet to the tunnel with a suitable guard to prevent the ingress of large objects into the rotodynamic machinery. The dimensions of the guard are to strike a balance between undue efficiency loss due to flow restriction and viscous losses, the size of object allowed to pass and susceptibility to clog with weed and other flow restricting matter.

2.1.8 The inlet profile of the tunnel is to be so designed as to provide a smooth uptake of water over the range of craft operating trims and avoid significant separation of the flow into the rotating machinery.

2.1.9 The leading edges of FRP tunnels are to be additionally reinforced by suitable means. Proposals are to be submitted as required by *Pt 8, Ch 5, 2.1 Water jet propulsion systems - Construction 2.1.2*.

2.1.10 Single or multiple water jet unit installations having a total rated power in excess of 500kW are to be contained within their own watertight compartment. Other arrangements for maintaining watertight integrity may be specially considered depending on the size and installation layout.

2.1.11 For details of machinery requirements, *see Pt 10, Ch 2 Gas Turbines*, Machinery Requirements.

2.2 Water jet propulsion systems - Installation

2.2.1 Standard units built for 'off the shelf' supply and which include the duct are to be installed strictly in accordance with the manufacturer`s instructions, *see also Pt 8, Ch 5, 2.1 Water jet propulsion systems - Construction 2.1.4*.

2.2.2 Integral water jet ducts are to be constructed in accordance with the manufacturer`s requirements and the relevant plans submitted as required by *Pt 8, Ch 5, 2.1 Water jet propulsion systems - Construction 2.1.2*.

2.2.3 Where load is transmitted into the transom and/or bottom shell, the thickness of the laminate adjacent to the jet unit is to be increased. The increase in thickness is to be not less than 50 per cent of the calculated transom and bottom laminate thicknesses respectively or 12 mm, whichever is the greater. Such reinforcement is to extend beyond the surrounding stiffening structure.

2.2.4 For `bolted in` units, hull receiving rings are to be of a material compatible with the hull. Scantlings of the receiving rings are to be as required by the jet unit manufacturer and suitably edge prepared prior to bonding in place. The receiving ring is to be installed using an approved laminating procedure. Where a manufacturer`s specification is not provided, full details are to be submitted.

2.2.5 Bolt sizes and spacings are to be specified by the manufacturer, and are to be of suitable marine grade, insulated as appropriate and locked by suitable means.

2.2.6 Where studs are proposed for the receiving ring(s), the remaining thickness below the depth of blind tap is to be not less than 0,2 times the thickness of the receiving ring or 5 mm whichever is the greater. Bottoms of all blind taps are to be free of sharp corners.

2.2.7 The use of approved alignment resins may be considered where accurate seating and faying surfaces are required. Details are to be submitted for consideration and approval.

2.2.8 Where a water jet unit forms an integral part of the hull structure, such units are to be installed using an approved laminating procedure and in accordance with the manufacturer`s instructions. Materials to be laminated are to be of compatible specifications.

2.2.9 Water jet units transmitting thrust into the transom structure are to be supported by a system of radial, athwartship and vertical stiffening. Drawings are to be accompanied by a set of detailed structural calculations. Where complex installations are proposed, a finite element model may be submitted in lieu of direct calculations.

2.2.10 Water jet units transmitting thrust to a bottom shell connection or intermediate tunnel connection are to be supported by additional stiffening, the details and calculations for which are to be submitted.

2.2.11 In general, sandwich skin laminates in way of water jet installations are to be brought together to form single skins complying with *Pt 8, Ch 5, 2.2 Water jet propulsion systems - Installation 2.2.3*. Proposals to use sandwich construction in way of installations will be specially considered, subject to the use of appropriate structural core materials and direct calculations being submitted in support.

2.2.12 Exposed edges of laminates subject to water flow are to be over laminated and protected by suitable means, proposals are to be submitted for consideration.

2.2.13 Where the jet-unit is an FRP premoulding of an approved type, the surface of the unit is to be suitably abraded and degreased prior to installation in the mould tool and subsequent over laminating of the main hull structure. Particular care is to be given to material compatibility of the resin system used for the premould and main hull laminate.

2.3 Foil support arrangements

2.3.1 The materials and construction of the lifting surface will be considered on a case by case basis.

2.3.2 The design and performance of the lifting surface is outside the scope of classification. However, when submitting structural plans for the hull connection installation, the designer/Builder is to define:

(a) Operating mode, i.e. fully submerged or surface piercing.
(b) Maximum operational speed for which approval is sought.
(c) Maximum, direct, bending, shear and torque loads generated by the foil at the point of attachment(s).
(d) The type of profile or section used, e.g. N.A.C.A.
(e) Supply of lift/drag profile.
(f) If the foil is fixed, movable or retractable.
(g) If the foil is fitted with control surfaces.
(h) If the vertical leg(s) act as a rudder(s).
(i) If shaft liners are carried to the foils at which support arrangements are provided.
(j) If water intakes/scoops are fitted.
(k) If propulsion units are fitted.

2.3.3 The scantlings and arrangements of foils and their supporting structure will be required to be specially considered in the following cases where:

(a) Propulsion units are incorporated within the foil.
(b) Foils carry shaft support arrangements.
(c) The foils are of novel design.

2.3.4 Where fully submerged foils are `built-in` to the hull, the attachment area is to be contained within a watertight compartment. The structural arrangements of *Pt 8, Ch 5, 2.4 Surface drive mountings* are to be complied with as appropriate.

2.3.5 Where foils are to be bolted to the structural foundation and not `built in`, calculations are to be submitted. These are to demonstrate that the effect of loading arising from high speed impact, grounding, fouling, etc is limited to failure of the bolted connection. In all cases the structural and watertight integrity of the craft is to be maintained.

2.3.6 Attachment points of foils are in all cases to be contained within a watertight compartment.

2.3.7 Foils attached by riveted means are, in addition, to comply with *Pt 7, Ch 2, 4.24 Butt straps*.

2.3.8 Bow fairing doors fitted on forward retracting bow foils are to be weathertight and are to comply with the requirements of *Pt 3, Ch 4 Closing Arrangements and Outfit*.

2.3.9 Aft bulkheads of bow foil compartments are to comply with the requirements for collision bulkheads as detailed in *Pt 8, Ch 3, 7.6 Collision bulkheads*.

2.3.10 Hydraulically operated retracting systems are to be equipped with low pressure alarms, together with a manual system of operation in the event of system failure.

2.3.11 A mechanical locking system is to be provided on retracting systems when the system is in both the operational and `stowed` conditions.

2.4 Surface drive mountings

2.4.1 Transoms through which surface drive systems pass and which are required to carry thrust, significant weight, torque, moment, etc. are to be adequately reinforced.

2.4.2 The thickness of transom laminate is to be not less than 50 per cent greater than the adjacent plating or as advised by the drive manufacturer, whichever is the greater.

2.4.3 Steering rams are to be mounted on suitably reinforced areas of laminate supported by additional internal stiffening, details are to be submitted for consideration.

2.5 Sea inlet scoops

2.5.1 Sea inlet scoops may be integral with or an appendage to the hull.

2.5.2 Scoops are to be suitably positioned to minimise ventilation.

2.5.3 Suitable protective arrangements are to be provided to minimise the ingress of debris. The net area through the proposed arrangement is to be not less than twice that of the valves connected to the scoop. Provision is to be made for clearing the scoops by the use of suitable means, proposals are to be submitted.

2.5.4 Scoops are to be contained within a watertight compartment.

2.5.5 The laminate thickness in way of integral scoops is to be not less than 50 per cent greater than that of the adjacent shell laminate, with additional reinforcement at the leading edge.

2.5.6 For all composite construction, scoops are to be fitted as bolted appendages.

2.5.7 For craft navigating in ice, the arrangements will be specially considered on an individual basis.

2.6 Lifting appliance support arrangements

2.6.1 Crane pedestals are to be efficiently supported and, in general, are to be carried through the deck and satisfactorily scarfed into the surrounding structure. Alternatively, crane pedestals may comprise of a foundation, in which case the foundation and its supporting structure are to be of substantial construction. Proposals for other support arrangements will be specially considered.

2.6.2 The pedestal or proposed arrangement is to be designed with respect to the worst possible combinations of loads resulting from the crane self weight, live load, wind and crane accelerations together with those resulting from the craft's heel and trim. The designer's calculations for loadings are to be indicated on the plans to be submitted.

2.6.3 Stowage arrangements are to be taken into account when calculating the loads applied to the pedestal.

2.6.4 The deck plating and underdeck stiffening in way of a lifting appliance pedestal are to be assessed using the same criteria used to assess the lifting appliance pedestal.

2.6.5 The support arrangements for life-saving appliances are in general, to be in accordance with *Pt 3, Ch 9, 6.5 Support structure for life-saving appliances* of the *Rules and Regulations for the Classification of Ships, July 2021*

2.6.6 The strength of composite lifting appliance pedestals (all failure modes) is to be assessed based on the ultimate tensile strength of the material using the limiting stress criteria given in *Table 7.3.1 Limiting stress criteria for local loading*

2.6.7 Direct FE calculations of the lifting appliance or life-saving appliance foundation, carried out in accordance with the requirements of *Pt 3, Ch 1, 2 Direct calculations*, are to be submitted for review. Calculations are to be based on ply theories or recognised multiaxial failure criteria. Details of the reporting and acceptance criteria are to be agreed beforehand. Alternatively, a full scale load test using the SWL (calculated in accordance with *Pt 8, Ch 5, 2.6 Lifting appliance support arrangements 2.6.2* or *Pt 8, Ch 5, 2.6 Lifting appliance support arrangements 2.6.5* as appropriate) divided by the limiting stress coefficient given in *Pt 8, Ch 5, 2.6 Lifting appliance support arrangements 2.6.6* is to be carried out. Details are to be agreed with LR prior to testing.

2.6.8 The deck laminate is to be additionally reinforced in way of lifting appliance foundations. The thickness of reinforcement is to be that required by the designer's calculations but in no case less than 50 per cent the thickness of the adjacent plating.

2.6.9 Laminate tapers are to be in accordance with *Pt 8, Ch 2, 3.9 Laminate detail*.

2.7 Skirt attachment

2.7.1 The design and scantlings of the skirt are, in general, outside the scope of classification, however the designer/builders are to submit their proposals in respect of the attachment detail. The following supporting information is to be submitted:

(a) Cushion pressure,
(b) Calculations demonstrating that the effect of damage to the flexible membrane and/or the retaining section arising from high speed impact, grounding, fouling, etc. will not compromise the structural and watertight integrity of the craft.

2.7.2 The skirt is to be securely attached around its periphery. The supporting structure is to be suitably reinforced by the use of tapping plates incorporated into the laminate.

2.7.3 Where the skirt is retained by bolting the retaining bars are to be as long as practicable, with the fasteners being spaced not more than 50 mm apart.

2.7.4 Where the design of the skirt is such that the flexible edge is retained by the use of a pre-formed channel, only the bolted connection of the preform to the hull structure is to be considered.

2.8 Trim tab arrangements

2.8.1 The shape, design and scantlings of the trim tab are outside the scope of classification, however Lloyd's Register (hereinafter referred to as 'LR') is concerned with their attachment to the hull structure.

2.8.2 The designer/Builder is to submit the following:

(a) Detailed calculations indicating the maximum lift force generated by the tab for which acceptance is sought together with the corresponding speed and displacement.
(b) Details of the hull attachment and loadings in way for the trim tab and actuation system.
(c) Details and calculations of the local internal reinforcement to resist the loading in way of the attachment.

2.8.3 Bearing materials used are to be of an approved type.

2.8.4 Fully submerged retractable trim tabs will be specially considered on a case by case basis.

2.9 Spray rails

2.9.1 Spray rails are, in general, to be integrated into the hull structure but may be added in the form of an appendage on completion of the hull shell.

2.9.2 Where spray rails are integrated, they are to have a laminate thickness not less than the adjacent bottom shell and additionally have section properties equivalent to that required for a longitudinal stiffener in the same position.

2.9.3 Where spray rails are added as an appendage, they are to be attached in accordance with an approved bonding/ laminating procedure and are additionally to comply with the strength requirements of *Pt 8, Ch 5, 2.9 Spray rails 2.9.2*. Composite preforms bonded to the outer hull are to be manufactured and bonded using approved materials, compatible with the hull laminate.

2.9.4 Spray rails are to be supported by the internal stiffening arrangements and by additional local reinforcement as necessary, as given in *Pt 8, Ch 3, 3.14 Local reinforcement*.

2.9.5 In no case are the toes of spray rails to terminate on unsupported shell laminate.

2.9.6 In sandwich construction the outer skin is to be a smooth continuous surface, with spray rails attached as required by *Pt 8, Ch 5, 2.9 Spray rails 2.9.3*.

2.10 Other lifting surfaces

2.10.1 Other lifting surfaces not specifically covered by the Rules will be individually considered on the basis of submitted direct calculations.

2.10.2 Structure or hull shapes above the running waterline designed to generate aerodynamic lift may be individually considered on a case by case basis.

2.10.3 Aerodynamic, hydrodynamic and aero-hydrodynamic stability are outside the scope of classification and are subject to the approval of the National Administration concerned.

2.11 Propeller ducting

2.11.1 Where propellers are fitted within ducts/tunnels the laminate weight in way of the blades is to be increased by 50 per cent.

2.11.2 The tunnel wall in way of the propeller blades is to be additionally stiffened.

2.12 Ride control ducting and installation for Surface Effect Ships (SES)

2.12.1 Ducts penetrating the side inboard shell plating are to comply with the scantling requirements for side inboard structures, over their entire length, in the appropriate material.

2.12.2 Ducts penetrating the wet-deck are to comply with the scantling requirements for wet-deck structures over their entire length, in the appropriate material.

2.12.3 Open ends of ducts are to be fitted with a suitable protective grille.

2.12.4 The vent assembly, its design, construction and operation, is outside the scope of classification and is the responsibility of the ride control system designer.

2.12.5 Details of the installation and securing arrangements of the vent valve assembly into the duct are to be submitted for approval.

2.13 Ramp supporting structure

2.13.1 The support structure (including hinges) in way of the interface between a ramp and the craft is to be assessed in accordance with the appropriate criteria given in *Ch 6, 2 Loading and design criteria* of the *Code for Lifting Appliances in a Marine Environment, July 2021*.

2.13.2 The loads that the ramp supporting structure will be subjected to are to be submitted by the designer or Shipbuilder. These loads are to be calculated in accordance with *Ch 6, 2 Loading and design criteria* of the *Code for Lifting Appliances in a Marine Environment, July 2021*. Load cases calculated in accordance with alternative standards can be accepted subject to agreement with LR.

2.13.3 Loads already existing in the supporting structure (other than those from the ramp) are to be superimposed if applicable.

2.13.4 Ramps forming part of the watertight integrity of the hull are also to be assessed in accordance with the applicable scantling requirements.

■ *Section 3* **Vehicle decks**

3.1 General

3.1.1 Where it is proposed to construct vehicle decks in FRP composite materials, each case will be subject to individual consideration. The scantlings are to be determined by direct calculation or on the basis of the requirements of *Pt 8, Ch 3 Scantling Determination for Mono-Hull Craft*, in conjunction with the procedures, loadings and general requirements for vehicle decks of aluminium alloy construction, as indicated in *Pt 7, Ch 5 Special Features*.

3.1.2 It is recommended that single skin laminate construction incorporating longitudinal or transverse stiffening be adopted. Where it is proposed to use sandwich skin construction, particular care is to be given to the selection of the core material. Such proposals will require to be specially considered, and testing may be required to demonstrate the suitability of the panels.

3.1.3 The deck and supporting structure are to be designed on the basis of the maximum loading to which they may be subjected in service. Where applicable, the hatch covers are to be similarly designed. In no case, however, are the scantlings to be less than would be required for a weather or cargo deck or hatch cover, as applicable.

3.1.4 Details of the deck loading resulting from the proposed stowage or operation of vehicles are to be supplied by the Builder. These details are to include axle and wheel spacing, the wheel load, type of tyre and tyre print dimensions for the vehicles. The vehicle types and wheel loads for which the vehicle decks, including hatch covers where applicable, have been approved are to be included in the craft's documentation and contained in a notice displayed on each deck. For design purposes, the wheel loading is to be taken as not less than 3,0 kN.

3.1.5 The scantling requirements are based on structural strength and limitations on stress and deflection, with no allowance made for wear and tear. Local reinforcement as given in *Pt 8, Ch 3, 3.14 Local reinforcement* is to be fitted as necessary, particularly in way of vehicle lanes and passenger routes.

3.1.6 Deck fittings in way of vehicle lanes are to be recessed.

3.2 Securing arrangements

3.2.1 Details of the loads and connections to the hull of vehicle securing arrangements are to be indicated on the plans submitted with the Designer`s calculations.

3.3 Access

3.3.1 Where access to the vehicle deck is provided by bow, side and stern doors, these openings are to comply with the requirements of *Pt 3, Ch 4, 4 Side and stern doors and other shell openings*.

3.3.2 Doors providing pedestrian access between vehicle decks and accommodation spaces are to be gastight, and have scantlings and fire restricting characteristics equivalent to the surrounding structure, *see also Pt 17 Fire Protection, Detection and Extinction*.

3.4 Hatch covers

3.4.1 The scantlings and arrangements of hatch covers located within vehicle decks are to be not less than those required by the Rules for the supporting structure in which such hatches are fitted. In general, the end fixity of primary stiffening members is to be taken as simply supported. Local and secondary stiffening members may be either partially or fully fixed at their end connections dependent upon the proposed arrangement.

3.4.2 In no case, however, are the scantlings of plate or sandwich laminates and stiffeners to be less than would be required for a weather or cargo deck, or hatch cover, as applicable.

3.4.3 Where unusual arrangements of hatch cover stiffening are proposed, the scantlings of plating and stiffeners may be determined by direct calculations using a two-dimensional grillage determination.

3.5 Heavy and special loads

3.5.1 Where heavy or special loads are proposed to be carried, the scantlings and arrangements of the deck structure will be individually considered on the basis of submitted calculations.

3.5.2 Due account is to be taken of the acceleration levels due to craft motion applicable to particular items of heavy mass such as vehicles, containers, pallets, etc.

3.6 Direct calculations

3.6.1 LR will consider direct calculations for the derivation of vehicle deck scantlings as an alternative and equivalent to those derived by Rule requirements. The assumptions made and the calculation procedures used are to be submitted for appraisal in accordance with *Pt 3, Ch 1, 2 Direct calculations*.

■ *Section 4* Movable decks

4.1 Classification

4.1.1 Movable decks other than those described in *Pt 8, Ch 5, 4.1 Classification 4.1.2* are not a classification item, although consideration is to be given to the associated supporting structure. Where movable decks are fitted, it is recommended that they are to be based on the requirements of this Section.

4.1.2 At the Owner's or Builder's request, however, movable decks will be included as a classification item, and the class notation **movable decks** will be entered in the *Register Book*. In such cases, all movable decks on board the craft are to comply with the requirements of this Section.

4.2 Arrangements and designs

4.2.1 Movable decks are generally to be constructed as pontoons comprising a web structure with top decking. Other forms of construction will be individually considered.

4.2.2 Positive means of control are to be provided to secure decks in the lowered position.

4.2.3 The decks are to be efficiently supported, and hinges, pillars, chains or other means (or a combination of these) are to be designed on the basis of the imposed loads. Where supporting chains and fittings are required, they are to have a factor of safety of at least two on the proof load.

4.2.4 Plans showing the proposed scantlings and arrangements of the system are to be submitted.

4.2.5 Where it is proposed to stow the pontoons on deck, when not in use, details of the proposals for racks, fittings, etc. are to be submitted for consideration.

4.3 Loading

4.3.1 The loading requirements for movable decks are to be in accordance with *Pt 8, Ch 5, 3.1 General*.

4.3.2 Where it is proposed also to use the decks for general cargo, the design loadings are to be submitted for consideration.

4.4 Scantling determination

4.4.1 The scantlings and arrangements of movable decks are to be not less than required by the Rules for the supporting structure in which they are fitted. In general the end fixity of primary stiffening members is to be taken as simply supported. Local and secondary stiffening members may be either partially or fully fixed at their end connections dependent upon the proposed arrangement.

4.5 Deflection

4.5.1 Where wheeled vehicles are to be used, the supporting arrangements are to be such that the movement at the edge of one pontoon relative to the next does not exceed 50 mm during loading or unloading operations.

4.6 Direct calculations

4.6.1 As an alternative to the requirements of *Pt 8, Ch 5, 4.3 Loading*, the structure may be designed on the basis of a direct calculation using a grillage idealisation. The method adopted and the stress levels proposed for the material of construction are to be submitted for consideration, *see also Pt 3, Ch 1, 2 Direct calculations*.

■ *Section 5* Helicopter landing areas

5.1 General

5.1.1 Where it is proposed to construct helicopter landing areas in FRP composite materials, each case will be subject to individual consideration.

5.1.2 Attention is drawn to the requirements and guidance of National and other Authorities concerning the construction of helicopter landing platforms and the operation of helicopters as they affect the ship. These include SOLAS Reg.II-2/18 and Reg.III/28 as applicable as well as the *International Chamber of Shipping (ICS) Guide to Helicopter/Ship Operations and the International Aeronautical Search and Rescue Manual (IAMSAR) and CAP437 Standards for Offshore Helicopter Landing Areas*.

5.1.3 Attention is drawn to the requirements of National and other Authorities concerning the construction of helicopter landing platforms and the operation of helicopters as they affect the craft.

5.1.4 Plans are to be submitted showing the proposed scantlings and arrangements of the structure. The type, size and weight of helicopters to be used are also to be indicated. Details of the helicopter types to be used are to be included in the craft`s documentation, and be contained in a notice displayed on the helicopter landing deck.

5.1.5 Where the landing area forms part of a weather or erection deck, the scantlings are to be not less than those required for decks in the same position.

5.1.6 The requirements for fire protection, detection and extinction are outside the scope of classification and are therefore to comply with requirements of the National Authority.

5.1.7 It is recommended that single skin laminate construction incorporating longitudinal or transverse stiffening is to be adopted. Where it is proposed to use sandwich skin construction, particular care is to be given to the selection of the core material; such proposals will require to be specially considered, and testing may be required to demonstrate the suitability of the panels.

5.2 Symbols

5.2.1 The symbols in this Section are as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1* and in the appropriate sub-Section.

5.3 Arrangements

5.3.1 The landing area is to be sufficiently large to allow for the landing and manoeuvring of the helicopter, and is to be approached by a clear landing and take-off sector complying in extent with the applicable regulations.

5.3.2 The landing area is to be free of any projections above the level of the deck. Projections in the zone surrounding the landing area are to be kept below the heights permitted by the regulations.

5.3.3 Suitable arrangements are to be made to minimise the risk of personnel or machinery sliding off the landing area. A non-slip surface and anchoring devices are to be provided.

5.3.4 Arrangements are to be made for drainage of the platform, including drainage of spilt fuel.

5.3.5 Details of the connections to the hull of helicopter securing arrangements are to be submitted for approval.

5.3.6 Engine uptake arrangements are to be sited such that exhaust gases cannot be drawn into helicopter engine intakes during helicopter take off or landing operations.

5.4 Loadings

5.4.1 The load cases to be investigated are to be not less than those required by *Pt 7, Ch 5, 6 Helicopter landing areas* for helicopter landing areas of aluminium alloy construction.

5.4.2 The proposed loadings are to be agreed with LR prior to scantling analysis and submission of structural plans for appraisal.

5.4.3 Details of the deck loading resulting from the proposed stowage arrangements of helicopters are to be supplied by the Builder. These details are to include the axle and wheel spacing, the wheel load, type of tyre and tyre print dimensions for the helicopter. For design purposes the wheel loading is to be taken as not less than 3,0 kN (0,3 tonne-f).

5.4.4 Where it is proposed also to use the decks for general cargo or other alternative use, the design loadings are to be submitted for consideration.

5.5 Scantlings

5.5.1 The scantlings and arrangements of helicopter landing areas are to be not less than those required by the Rules for the supporting structure in which the helicopter landing areas are fitted. In general the end fixity of primary stiffening members is to be taken as simply supported. Local and secondary stiffening members may be either partially or fully fixed at their end connections dependent upon the proposed arrangement.

■ *Section 6*
Strengthening requirements for navigation in ice conditions

6.1 General

6.1.1 Where an ice class notation is to be included in the class of a craft, the scantlings will require special consideration, *see Pt 3, Ch 2, 9 Navigation in ice*.

6.2 Shell laminate

6.2.1 It is assumed that single skin laminate construction incorporating longitudinal or transverse stiffening will be adopted. Where it is proposed to use sandwich skin construction, particular care is to be given to the selection of the core material; such proposals will require to be specially considered, and testing may be required to demonstrate the suitability of the panels.

6.2.2 In way of the main ice belt zone, the thickness of the shell laminate is to be determined by direct calculation. A copy of these calculations is to be submitted for consideration.

6.2.3 Changes in laminate thicknesses are to take place gradually, and in no case is the length of taper to be less than 20 times the difference in thickness. Additionally individual plies of the laminate are to be arranged such that any delamination will be directed to the outer surface of the laminate.

6.3 Shell framing

6.3.1 The web thickness for ice framing members of top-hat or plate section is to be determined by direct calculation. A copy of these calculations is to be submitted for consideration.

6.3.2 Ice frames are to be attached to the shell plating by double primary bonding angles in accordance with *Pt 8, Ch 3, 1.19 Boundary bonding*. The web area of ice frames is to be maintained; air and drain holes are to be kept to a minimum.

6.3.3 The bending moment assumed to be carried by the ice framing stiffening member is not to be taken as less than 50 per cent greater than that required by the appropriate Section of the Rules for the stiffening member subjected to hydrostatic or pitching pressure whichever is the greater.

6.4 Stem construction

6.4.1 The stem is to be additionally protected/reinforced by a metallic shoe or other equivalent arrangement. The shoe/ reinforcement is to extend from the keel plate to 750 mm above the ice load waterline and is to be internally strengthened by closely spaced floors, brackets or webs. Details of such protection and the method of attachment are to be submitted for consideration.

6.4.2 Attachment by mechanical means such as bolting or other methods is not to impair the watertight integrity of the craft. Through bolting of the hull is to be kept to a minimum and avoided where practicable.

■ *Section 1* General

1.1 Application

1.1.1 The requirements for longitudinal and transverse global strength for both mono-hull and multi-hull craft of composite construction, are contained within this Chapter. Due consideration is taken of the dynamic effects, where appropriate, in both the crest and trough wave landing conditions.

1.2 Symbols and definitions

1.2.1 Unless specified otherwise the symbols used in this Chapter are defined as follows:

a_i = cross sectional area of the individual ply, *i*, in m^2

E_i = E_{ti}, or E_{ci} of the individual ply *i*, relative to its position above or below the neutral axis, in N/mm^2

E_{ci} = compressive modulus of individual ply, *i*, in N/mm^2

E_{ti} = tensile modulus of individual ply, *i*, in N/mm^2

I_i = inertia of the of individual ply, *i*, about the neutral axis, in mm^4

M_R = the appropriate Rule bending moment, as defined in *Pt 5, Ch 5 Global Load and Design Criteria*

Q_R = the appropriate Rule shear force, as defined in *Pt 5, Ch 5 Global Load and Design Criteria*

$\Sigma(E_i I_i)_H$ = total $(E I)_H$ (stiffness) for the hull midship section, in Nm^4/mm^2

σ_{ci} = compressive stress within an individual element, *i*, in N/mm^2

σ_{ti} = tensile stress within an individual element, *i*, in N/mm^2

τ_H = shear stress at any position along the length of the craft, in N/mm^2

x_i = the distance to the centre of area of the individual ply, *i*, from the outer surface of the keel plate laminate, in metres

y_i = vertical distance from the hull transverse neutral axis to the centre of the individual ply, in metres

y_{NA} = the distance of the neutral axis, from the outer surface of the keel plate laminate, in metres

L_R and B are as defined in *Pt 3, Ch 1, 6.2 Principal particulars*.

1.2.2 The strength deck is to be taken as follows:

(a) Where there is a complete upper deck the strength deck is the upper deck.
(b) Where the upper deck is stepped, as in the case of raised quarterdeck craft, the strength deck is stepped as shown in *Figure 6.1.1 Strength deck*.

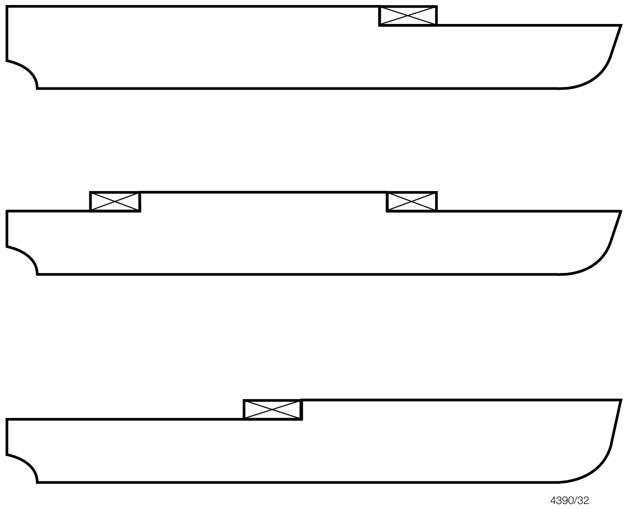


Figure 6.1.1 Strength deck

1.3 General

1.3.1 The additional pressures arising from the influence of the global loading are considered in the determination of the longitudinal strength requirements for local and secondary stiffening and bottom shell laminate.

1.3.2 All continuous longitudinal structural material is to be included in the calculation of the stiffness, $(E\ I\ )_H$, of the hull midship section, and the lever, y_i, is to be measured vertically from the neutral axis to the centre of the individual ply, *i*. The inertia of an individual horizontal ply, *i*, about its own axes is to be ignored.

1.3.3 Structural members which contribute to the overall hull girder strength are to be carefully aligned so as to avoid discontinuities resulting in abrupt variations of stresses and are to be kept clear of any form of openings which may affect their structural performance.

1.3.4 In general, superstructures or deckhouses will not be accepted as contributing to the global longitudinal or transverse strength of the craft. However, where it is proposed to include substantial, continuous stiffening members, special consideration will be given to their inclusion on submission of the designer's/builder's calculations. Such calculations are to make due allowance for superstructure efficiency. *See also Pt 7, Ch 6, 2.5 Superstructures global strength*.

1.3.5 Where continuous deck longitudinals or deck girders are arranged above the strength deck, special consideration may be given to the inclusion of their sectional area in the calculation of the hull stiffness $(E\ I\ )_H$. The lever is to be taken to a position corresponding to the depth of the longitudinal member above the moulded deckline at side amidships. Each such case will be individually considered.

1.3.6 Adequate transition brackets are to be fitted at the ends of effective continuous longitudinal strength members in the deck and bottom structures.

1.3.7 Scantlings of all continuous longitudinal members of the hull girder based on the minimum section stiffness requirements given in *Pt 8, Ch 6, 2.2 Bending strength* are to be maintained within $0{,}4L_R$ amidships. However, in special cases, based on consideration of type of ship, hull form and loading conditions, the scantlings may be gradually reduced towards the ends of the $0{,}4L_R$ part, bearing in mind the desire not to inhibit the vessel's loading and operational flexibility. L_R is as defined in *Pt 8, Ch 6, 1.2 Symbols and definitions 1.2.1*.

1.4 Openings

1.4.1 Deck openings having a length in the fore and aft directions exceeding $0{,}1B$ m or a breadth exceeding $0{,}05B$ m, are always to be deducted from the sectional areas used in the section stiffness calculation. *B* is as defined in *Pt 8, Ch 6, 1.2 Symbols and definitions 1.2.1*.

1.4.2 Deck openings smaller than stated in *Pt 8, Ch 6, 1.4 Openings 1.4.1* including manholes, need not be deducted provided they are isolated and the sum of their breadths or shadow area breadths (*see Pt 8, Ch 6, 1.4 Openings 1.4.3*), in one transverse section does not exceed 0,06 (B_1 - Σb_1).

where

B_1 = breadth of craft at section considered

Σb_1 = sum of breadths of deductible openings.

Where a large number of deck openings are proposed in any transverse space, special consideration will be required.

1.4.3 Where calculating deduction-free openings, the openings are assumed to have longitudinal extensions as shown by the shaded areas in *Figure 6.1.2 Isolated openings*. The shadow area is obtained by drawing two tangent lines to an opening angle of 30°. The sections to be considered are to be perpendicular to the centreline of the ship and are to result in the maximum deduction in each transverse space.

1.4.4 Isolated openings in longitudinals or longitudinal girders need not be deducted if their depth does not exceed 25 per cent of the web depth or 75 mm whichever is the lesser.

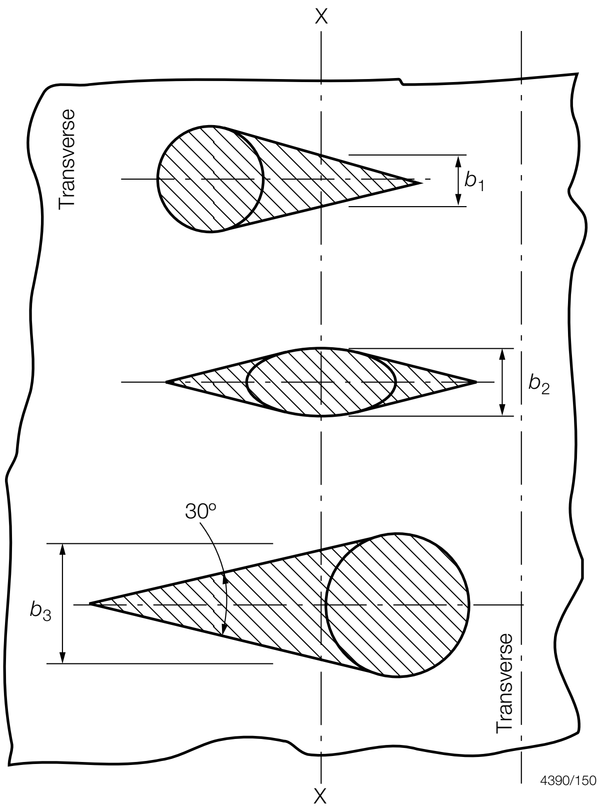
1.4.5 Openings are considered isolated if they are spaced not less than 1 m apart.

1.4.6 A reduction for drainage holes and scallops in beams and girders, etc. is not necessary so long as the original section stiffness at deck or keel is reduced by no more than three per cent.

1.5 Direct calculation procedure

1.5.1 In direct calculation procedures capable of deriving the wave induced loads on the ship, and hence the required modulus, account is to be taken of the ship's actual form and weight distribution.

1.5.2 Lloyd's Register's (hereinafter referred to as 'LR') direct calculation method involves derivation of response to regular waves by strip theory, short-term response to irregular waves using the sea spectrum concept, and long-term response predictions using statistical distributions of sea states. Other direct calculation methods submitted for approval are normally to contain these three elements and produce similar and consistent results when compared with LR's methods.



Total equivalent breadth of small openings at XX = $b_1 + b_2 + b_3$

Figure 6.1.2 Isolated openings

1.6 Approved calculation systems

1.6.1 Where the assumptions, method and procedures of a longitudinal strength calculation system have received general approval from LR, calculations using the system for a particular ship may be submitted.

1.7 Information required

1.7.1 In order that an assessment of the longitudinal strength requirements can be made, the following information is to be submitted, in LR's standard format where appropriate:

(a) General arrangement and capacity plan or list, showing details of the volume and position of centre of gravity of all tanks and compartments.
(b) Bonjean data, in the form of tables or curves, for at least 21 equally spaced stations along the hull. A lines plan and/or Tables of offsets may also be required.
(c) Details of the calculated lightweight and its distribution.
(d) Details of the weights and centres of gravity of all deadweight items for each of the main loading conditions. It is recommended that this information be submitted in the form of a preliminary Loading Manual, and that it includes the calculated still water and dynamic bending moments and shear forces.

1.8 Loading guidance information

1.8.1 Sufficient information is to be supplied to the Master of every craft to enable him to arrange loading in such a way as to avoid the creation of unacceptable stresses in the craft's structure.

■ Section 2
Hull girder strength for mono-hull craft

2.1 General

2.1.1 Longitudinal strength calculations are to be submitted for all craft with a Rule length, L_R, exceeding 40 m, covering the range of load and ballast conditions proposed, in order to determine the required hull girder strength. Still water, static wave and dynamic bending moments and shear forces are to be calculated for both departure and arrival conditions.

2.1.2 For craft of ordinary hull form with a Rule length, L_R, less than 40 m, the minimum hull girder strength requirements are generally satisfied by scantlings obtained from local strength requirements. However, longitudinal strength calculations may be required at LR's discretion dependent upon the hull form, constructional arrangement and proposed loading.

2.1.3 Where the Rule length, L_R, of the craft exceeds 65 m, or for new designs of large, structurally complicated craft, the design loads and scantling determination formulae in this Chapter are to be supplemented by direct calculation and structural analysis by 3-D finite element methods. These supplementary calculations are to include the results of model tests and full scale measurement where available or required by LR. Full details of such methods and all assumptions and calculations, which are to be based on generally accepted theories, are to be submitted for appraisal.

2.2 Bending strength

2.2.1 The effective geometric properties of the midship section are to be calculated directly from the dimensions of the section using only the effective material elements which contribute to the global longitudinal strength. For the purposes of this analysis an element may be a deck plating, longitudinal girder, inner bottom, etc. or other continuous member.

2.2.2 The distance of the neutral axis, y_{NA}, from the outer surface of the keel plate laminate may be determined from the following:

$$y_{NA} = \frac{\sum\left(E_i a_i x_i\right)}{\sum\left(E_i a_i\right)_H} \text{ m}$$

2.2.3 The resultant compressive stress within an individual ply, *i*, may be determined from the following:

$$\sigma_{ci} = \frac{E_{ci} y_i M_R}{\Sigma\left(E_i I_i\right)_H} \times 10^{-3} \text{ N/mm}^2$$

2.2.4 The resultant tensile stress within an individual ply, *i*, may be determined from the following:

$$\sigma_{ti} = \frac{E_{ti} y_i M_R}{\sum\left(E_i I_i\right)_H} \times 10^{-3} \text{ N/mm}^2$$

2.2.5 The ultimate tensile and compressive strengths of the laminate or face reinforcement which form an element, may be determined from suitable tests or alternatively may be predicted using classical stress/strain relationships with due account being taken of the amounts of different materials and their associated strain rates to failure. In this respect materials which are incompatible in terms of their strain rates to failure are not to be mixed. Where materials are mixed the requirements of *Pt 8, Ch 6, 2.2 Bending strength 2.2.6* for reserve factors are to be complied with when a first ply failure analysis is carried out.

2.2.6 The allowable tensile and compressive stress limits indicated in *Table 7.3.2 Limiting stress criteria for global loading* are to be complied with.

2.3 Shear strength

2.3.1 The shear strength of the craft at any position along the length is to be examined. The shear stress, τ_H, is determined from the following:

$$\tau_H = \frac{Q_R}{A_\tau} \times 10^{-3} \text{ N/mm}^2$$

where

A_τ = effective shear area of transverse section, in m^2, to be taken as the net sectional area of the side shell plating and the longitudinal bulkheads after deductions for openings, in m^2.

2.3.2 The allowable shear stress limits indicated in *Table 7.3.2 Limiting stress criteria for global loading* are to be complied with.

2.4 Torsional strength

2.4.1 Torsional stresses are typically small for ordinary mono-hulls less than 65 m in Rule length, L_R, and can generally be ignored.

2.4.2 The calculation of torsional stresses and/or deflections may be required when considering craft with unusual form or proportions, or with large deck openings. In general, calculations may be required to be carried out using a direct calculation procedure. Such calculations are to be submitted in accordance with *Pt 8, Ch 6, 1.5 Direct calculation procedure*.

■ *Section 3*
Hull girder strength for multi-hull craft

3.1 Application

3.1.1 Except as otherwise specified within this Section, the global strength requirements for multi-hull craft are to comply with *Pt 8, Ch 6, 2 Hull girder strength for mono-hull craft*.

3.1.2 Longitudinal strength calculations are to be submitted for all craft with a Rule length, L_R, exceeding 35 m, covering the range of load conditions proposed, in order to determine the required hull girder strength. Still water, static wave and dynamic bending moments and shear forces are to be calculated for both departure and arrival conditions and for any special mid-voyage conditions caused by changes in ballast distribution.

3.1.3 For craft of ordinary hull form with Rule length, L_R, less than 35 m, the minimum hull girder strength requirements are generally satisfied by scantlings obtained from local strength requirements. However, longitudinal strength calculations may be required at LR's discretion dependent upon the hull form, constructional arrangement and proposed loading.

3.1.4 Where the Rule length, L_R, of the craft exceeds 50 m, or for new designs of large, structurally complicated craft, the design loads and scantling determination formulae in this Chapter are to be supplemented by direct calculation and structural analysis by 3-D finite element methods. These supplementary calculations are to include the results of model tests and full scale measurement where available or required by LR. Full details of such methods and all assumptions and calculations, which are to be based on generally accepted theories, are to be submitted for appraisal.

3.1.5 The strength deck plating in way of the cross-deck structure, the wet-deck plating, longitudinal bulkheads and girders, and other continuous members may be included in the determination of the midship section stiffness.

3.1.6 Special consideration will be given to the global strength requirements for craft with more than two hulls linked by cross-deck structure.

3.2 Hull longitudinal bending strength

3.2.1 The requirements of *Pt 8, Ch 6, 2.2 Bending strength* are to be complied with, using the appropriate design bending moment applicable to multi-hull craft, as determined from *Pt 5, Ch 5, 5 Design criteria and load combinations*.

3.2.2 The allowable tensile and compressive stress limits indicated in *Table 7.3.2 Limiting stress criteria for global loading* are to be complied with.

3.3 Hull shear strength

3.3.1 The requirements of *Pt 8, Ch 6, 2.3 Shear strength* are to be complied with in so far as they are applicable.

3.3.2 The allowable shear stress limits indicated in *Table 7.3.2 Limiting stress criteria for global loading* are to be complied with.

3.4 Torsional strength

3.4.1 At the discretion of LR or where a craft is of unusual form or novel construction, the torsional stress is to be determined by direct calculation methods using the twin hull torsional connecting moment as defined in *Pt 5, Ch 5 Global Load and Design Criteria*. Such calculations are to be submitted in accordance with *Pt 8, Ch 6, 1.5 Direct calculation procedure*.

3.5 Strength of cross-deck structures

3.5.1 Cross-deck structures are to have adequate transverse strength in relation to the design loads and moments. Generally the net areas with effective flange, after deductions of openings, are to be used for the calculations of the total stiffness of the longitudinal section of the cross-deck structures. The effective shear area of transverse strength members is the net web area after deduction of openings.

3.5.2 The twin hull transverse bending strength of the craft at any position along the length is to be examined.

3.5.3 The twin hull transverse bending stresses for both the compressive and tensile cases are to be determined by direct calculation methods, or on the basis of *Pt 8, Ch 6, 2.2 Bending strength 2.2.3* and *Pt 8, Ch 6, 2.2 Bending strength 2.2.4* respectively. The stresses are to be determined in conjunction with the twin hull transverse bending moment, M_R, as defined in *Pt 5, Ch 5, 5 Design criteria and load combinations*.

3.5.4 Due consideration is to be given to the increased bending moments which may arise due to local point loadings from pillars, fuel bunkers, heavy items of machinery, stores, etc.

3.5.5 The shear strength of the cross-deck structure is to be examined by applying the appropriate vertical shear force at the centreline of the cross-deck structure between the twin hulls. The shear stress, τ_V, is to be determined from:

$$\tau_V = \frac{Q_R}{A_\tau} \times 10^{-3} \text{ N/mm}^2$$

where

A_τ = the net cross sectional area of the primary transverse cross-deck structure, in m^2

Q_R = is defined in *Pt 8, Ch 6, 1.2 Symbols and definitions 1.2.1*

3.5.6 The allowable shear stress limits indicated in *Table 7.3.2 Limiting stress criteria for global loading* are to be complied with.

3.6 Grillage structures

3.6.1 For complex girder systems, a complete structural analysis using numerical methods may be required to be performed to demonstrate that the stress levels are acceptable when subjected to the most severe and realistic combination of loading conditions intended, *see also Pt 8, Ch 3, 4.15 Grillage structures*.

3.6.2 In general, the transverse and vertical girders, bottom and side structures, bridge structure, deck structures and any other parts of the craft which LR considers critical to the craft's structural integrity are to be included in the numerical modelling of the craft.

3.7 Analysis techniques

3.7.1 General or special purpose computer programs or any other analytical techniques may be used provided that the effects of bending, shear, axial and torsion are properly accounted for and the theory and idealisation used can be justified.

3.7.2 In general, grillages consisting of slender girders may be idealised as frames based on beam theory provided proper account of the variations of geometric properties is taken. For cases where such an assumption is not applicable, finite element analysis or equivalent methods may have to be used.

3.7.3 Analysis of the cross deck structures with regard to impact loads due to slamming may have to be carried out using advanced structural analysis techniques.

Section

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull and multi-hull craft of composite construction as defined in *Pt 8, Ch 1, 1.1 General*.

1.2 General

1.2.1 The failure modes criteria contained within this Chapter are to be used in formulae from the preceding Chapters to determine the scantling requirements. In addition, they are to be used when direct calculations are proposed as an alternative.

1.3 Symbols and definitions

1.3.1 The symbols and definitions applicable to this Chapter are defined below or in the appropriate Section.

f_δ = span/deflection ratio

1.3.2 The slamming zone area referred to in this Chapter is defined as the region where the operational non-displacement mode pressures exceed the operational displacement mode pressures.

1.4 Direct calculations

1.4.1 The requirements of this Section may be modified where direct calculation procedures are adopted to analyse the various failure modes.

1.5 Equivalents

1.5.1 Where direct calculations are proposed, the requirements of *Pt 3, Ch 1, 2 Direct calculations* are to be complied with.

1.5.2 In addition, with the agreement of Lloyd's Register (hereinafter referred to as 'LR'), tests may be conducted to demonstrate the actual response of the structure and the results verified against the failure mode criteria in this Chapter.

■ *Section 2* Deflection control

2.1 General

2.1.1 The requirements in respect of limiting deflection for both panels and stiffening members are given in this Section. These limits are generally based on a span/deflection ratio, f_δ, as given in *Table 7.2.1 Limiting span/deflection ratio*, in consistent units.

2.1.2 Notwithstanding the values in *Table 7.2.1 Limiting span/deflection ratio*, the span/deflection ratio for panels subject to long-term static loading is to be less than 100.

Table 7.2.1 Limiting span/deflection ratio

Item		f_{δ}
Shell envelope		
	• sandwich construction	100
Bottom structure		
	• secondary stiffening	150
	• primary girders and web frames	200
Side structure		
	• secondary stiffening	150
	• primary girders and web frames	200
Main/strength deck structures		
	• sandwich construction	100
	• secondary stiffening	200
	• primary girders and web frames	250
	• hatch covers	100
Superstructure/deckhouse laminates		
(a) Generally	• sandwich construction	50
(b) Coachroof	• sandwich construction	
	• sandwich construction	100
(c) House top		50
(d) Lower/inner decks and house top subject to personnel loading		
	• sandwich construction	100
Superstructure/deckhouse stiffeners		
(a) Generally	• secondary	100
	• primary	150
(b) Coachroof	• secondary	150
	• primary	200
(c) House top	• secondary	100
	• primary	100
(d) Lower/inner decks and house top subject to personnel loading		
	• secondary members	150

	• primary members	200
Deep tank structures		
(a) Laminates	• sandwich construction	100
	• secondary members	100
(b) Stiffeners	• primary members	200
Watertight bulkhead structures		
(a) Laminates	• sandwich construction	50
	• secondary members	50
(b) Stiffeners	• primary members	150
Multihull cross-deck structures		
(a) Laminates	• sandwich construction	100
	• secondary members	125
(b) Stiffeners	• primary members	150
Vehicle deck structures		
(a) Laminates	• sandwich construction	100
(b) Stiffeners	• secondary members	200
	• primary members	250
Helicopter/flight decks		
(a) Laminates	• sandwich construction	100
(b) Stiffeners	• secondary members	200
	• primary members	250
Note Where significant curvature exists over the span of the stiffener or breadth of the panel, the allowable deflections will be specially considered.		

■ *Section 3*
Stress control

3.1 General

3.1.1 The nominal limiting stress for panels and primary and secondary stiffening members, subject to local and global loading conditions, are given in this Section.

3.2 Tensile and compressive stress

3.2.1 The limiting tensile and compressive stress criteria values for local and global loading conditions are given in *Table 7.3.1 Limiting stress criteria for local loading* and *Table 7.3.2 Limiting stress criteria for global loading* respectively. These values are expressed as a fraction of the ultimate tensile and compressive strength of the laminate at first ply failure.

3.2.2 The ultimate compressive strength of the sandwich skin laminate shall not be taken greater than the critical skin buckling stress given by

$$\sigma_{cr} = 0{,}5\,(E_{cps}\,E_c\,G)^{1/3}$$

where

σ_{cr} = critical skin buckling stress, in N/mm^2

E_c = compressive modulus of the core material, in N/mm^2

E_{cps} and G are as defined in *Pt 8, Ch 3, 1.5 Symbols and definitions 1.5.1*

3.3 Shear stress

3.3.1 The limiting shear stress criteria values for local and global loadings are given in *Table 7.3.1 Limiting stress criteria for local loading* and *Table 7.3.2 Limiting stress criteria for global loading* respectively. These values are expressed as a fraction of the ultimate shear strength of the laminate.

3.4 Interlaminar shear stress

3.4.1 The interlaminar shear strength of the proposed laminate is to be demonstrated to be not less than 13,8 N/mm^2.

3.5 Core shear stress

3.5.1 The limiting core shear stress criteria values are given in *Table 7.3.3 Limiting core shear stress criteria*. These values are expressed as a fraction of the ultimate core shear strength of the core material, *see also Pt 8, Ch 3, 1.14 Mechanical properties sandwich laminates 1.14.9*.

3.5.2 The ultimate core shear strength of the core material is to be taken as 90 per cent of the mean ultimate shear strength determined from accepted mechanical tests, or the mean minus two standard deviations based on a minimum of five samples, whichever is less. All test pieces are to be representative of the product to be manufactured and details are to be submitted for consideration.

3.5.3 In the absence of suitable test data, LR will consider basing the ultimate core shear strength on manufacturer recommended minimum design values based on mechanical tests performed by the core material manufacturer using accepted test methods.

Table 7.3.1 Limiting stress criteria for local loading

Item	Limiting stress fraction		
	Tensile	Compressive	Shear
Shell envelope:			
(a) Bottom shell laminate:			
• slamming zone	0,28	0,28	–
• elsewhere	0,25	0,25	–
(b) Side shell laminate:			
• slamming zone	0,33	0,33	–
• elsewhere	0,30	0,30	–
(c) Keel	0,25	0,25	–
Bottom structure:			
(a) Secondary stiffening:			

• slamming zone	0,33	0,33	0,33
• elsewhere	0,30	0,30	0,30
(b) Primary girders and web frames	0,33	0,33	0,33
(c) Engine girders	0,33	0,33	0,33
Side structure:			
(a) Secondary stiffening:			
• slamming zone	0,33	0,33	0,33
• elsewhere	0,30	0,30	0,30
(b) Primary girders and web frames	0,33	0,33	0,33
Main/strength deck laminate and stiffeners:			
(a) Laminate	0,30	0,30	–
(b) Secondary stiffening	0,30	0,30	0,30
(c) Primary girders and web frame	0,33	0,33	0,33
(d) Hatch covers	0,25	0,25	0,25
Superstructures/deckhouses:			
(a) Deckhouse front, 1st tier:			
• laminate	0,30	0,30	–
• stiffening	0,33	0,33	0,33
(b) Deckhouse front, upper tiers:			
• laminate	0,30	0,30	–
• stiffening	0,33	0,33	0,33
(c) Deckhouse, aft and sides:			
• laminate	0,30	0,30	–
• stiffening	0,33	0,33	0,33
(d) Coachroof:			
• laminate	0,30	0,30	–
• stiffening	0,33	0,33	0,33
(e) House top, not subject to personnel loading:			
• laminate	0,40	0,40	–
• stiffening	0,40	0,40	0,40
(f) Lower/inner decks and house top subject to personnel loading:			
• laminate	0,33	0,33	–
• stiffening	0,30	0,30	0,30
Bulkheads:			
(a) Collision bulkhead:			

• laminate	0,26	0,26	–
• secondary stiffening	0,32	0,32	0,32
• primary stiffening	0,32	0,32	0,32
(b) Watertight bulkhead:			
• laminate	0,33	0,33	–
• secondary stiffening	0,40	0,40	0,40
• primary stiffening	0,40	0,40	0,40
(c) Watertight bulkhead doors:			
• in collision bulkhead	0,25	0,25	–
• in other bulkheads	0,33	0,33	–
(d) Structure supporting watertight doors:			
• in collision bulkhead	0,25	0,25	0,25
• in other bulkheads	0,33	0,33	0,33
(e) Minor bulkheads:			
• laminate	0,50	0,50	–
• secondary stiffening	0,50	0,50	0,50
• primary stiffening	0,50	0,50	0,50
(f) Deep tank bulkheads:			
• laminate	0,25	0,25	–
• secondary stiffening	0,33	0,33	0,33
• primary stiffening	0,33	0,33	0,33
Multihull cross-deck structure:			
(a) Laminate:			
• slamming zone	0,33	0,33	–
• elsewhere	0,30	0,30	–
(b) Secondary stiffening:			
• slamming zone	0,33	0,33	0,33
• elsewhere	0,30	0,30	0,30
(c) Primary stiffening	0,33	0,33	0,33
Vehicle deck:			
(a) Laminate	0,25	0,25	–
(b) Secondary stiffening	0,33	0,33	0,33
(c) Primary stiffening	0,33	0,33	0,33
Helicopter/flight decks:			

(a) Normal usage:			
• laminate	0,25	0,25	–
• secondary stiffening	0,33	0,33	0,33
• primary stiffening	0,33	0,33	0,33
(b) Emergency landing:			
• laminate	0,33	0,33	–
• secondary stiffening	0,43	0,43	0,43
• primary stiffening	0,43	0,43	0,43
Lifting appliance pedestal/foundation structural elements:			
(a) cargo cranes	0,25	0,25	0,25
(b) structures exposed to permanent static loads	0,22	0,22	0,22
(c) LSA davit foundations, *see also Pt 8, Ch 5, 2.6 Lifting appliance support arrangements*.	0,22	0,22	0,22

Table 7.3.2 Limiting stress criteria for global loading

Operational mode of craft	Limiting stress fraction			
	Tensile	Compressive	Shear *see* Note 1	Shear *see* Note 2
$\Gamma \geq 3,0$ or $\Delta \leq 0,04(L_R B)^{1,5}$	0,33	0,33	0,33	0,33
$\Gamma < 3,0$ and $\Delta > 0,04(L_R B)^{1,5}$	0,25	0,25	0,25	0,25

Note 1. Limiting stress fraction for the hull shear stress at any point along the craft length.

Note 2. Limiting stress fraction for the vertical shear stress for the cross-deck structure.

Note

Δ = is the displacement as defined in *Pt 5, Ch 2, 2 Definitions and symbols*.

Note

Γ = is the Taylor Quotient as defined in *Pt 5, Ch 2, 2.1 Parameters to be used for the determination of load and design criteria 2.1.16*.

Note

L_R and B = are as defined in *Pt 3, Ch 1, 6.2 Principal particulars*.

Table 7.3.3 Limiting core shear stress criteria

Core Material	Limiting shear stress fraction
PVC	0,45
All other cores	0,35

Section 4
Buckling control

4.1 General

4.1.1 The requirements in respect of the control of buckling of single skin and sandwich panels, including global buckling of structures, pillars and pillar bulkheads are given in this Section.

4.2 Single skin laminate

4.2.1 Where single skin laminate panels are subject to compressive loading likely to cause axial buckling, design calculations are to be submitted indicating the margin against failure.

4.3 Sandwich skin laminate

4.3.1 Where sandwich panel skin laminates are subject to compressive loading likely to cause axial buckling, design calculations are to be submitted indicating the margin against failure.

4.3.2 Where sandwich panels subject to compressive loading have skin thicknesses which are less than the minimum required by *Pt 8, Ch 3, 2.3 Sandwich skin laminate*, design calculations are to be submitted indicating the margin against failure due to wrinkling of the sandwich skin laminates.

4.3.3 Where production methods or the craft design gives rise to local distortion or irregularity of the sandwich, the designer is to make due allowance for the reduction in critical wrinkling stress.

4.4 Pillars and pillar bulkheads

4.4.1 In general, the requirements in respect of the control of buckling of pillars and pillar bulkheads are given in *Pt 8, Ch 3, 10 Pillars and pillar bulkheads*.

Section 5
Impact control

5.1 General

5.1.1 Skin thicknesses may be accepted which are below the stated Rule minima indicated throughout the Rules provided that acceptable stress levels are predicted for the in service condition and that equivalent impact strength can be demonstrated to the satisfaction of LR. In such cases due consideration is to be given to providing a satisfactory water barrier and ensuring suitability to resist abrasion, local point loadings, etc. *see Pt 8, Ch 3, 2 Minimum thickness requirements*.

5.2 Testing

5.2.1 All impact tests are to be comparative tests using the Rule basic laminate as the comparative standard. Original and tested samples of both the proposed laminate and the Rule comparison laminate are to be submitted for LR's consideration together with a detailed test report. Testing is to be carried out by the Builder and witnessed by the LR Surveyor or at an independent testing establishment, acceptable to LR. Comparison will be by visual inspection only and interpretation of the results will be at the sole discretion of LR.

Section 6
Temperature control of cored sandwich structures

6.1 General

6.1.1 Where foam core materials are used in sandwich construction the properties at elevated temperature are to be considered. Where appropriate the mechanical properties are to be those at the maximum ambient temperature expected under normal operating conditions.

6.1.2 Alternatively other methods of controlling the temperature of the core may be considered, e.g. inserts, insulation.

6.2 Information required

6.2.1 The source of the mechanical properties data is to be shown on the Materials Data Sheet (Form 2075) when the plans are initially submitted for approval.

6.2.2 Test data is to be submitted for each grade of foam core in respect of:

- Core shear strength.
- Core shear modulus.
- Tensile strength (only for high density cores, i.e. > 100 kg/m^3).
- Tensile modulus (only for high density cores, i.e. > 100 kg/m^3).

6.3 Testing

6.3.1 Core materials are to be tested in accordance with *Rules for the Manufacture, Testing and Certification of Materials, July 2021*.

6.4 National Authority requirements

6.4.1 National Authority requirements are to be complied with as applicable.

Contents

Section

■ *Section 1* General requirements

1.1 Application

1.1.1 *Pt 9 General Requirements for Machinery* to *Pt 16 Control and Electrical Engineering* apply to the design, construction, installation and testing of:

- Main propulsion machinery systems.
- Essential auxiliary machinery systems, excluding the crankshaft for diesel engines intended for essential services where power does not exceed 110 kW.
- Steering and manoeuvring systems.

together with their associated equipment, pressure plant, piping systems, control engineering and electrical engineering systems for seagoing craft of the types stated in *Pt 1, Ch 2, 1 Conditions for classification*.

1.1.2 Machinery for non-seagoing craft is to comply with the requirements of *Pt 5 Main and Auxiliary Machinery* of the *Rules and Regulations for the Classification of Inland Waterways Ships, July 2021*.

1.1.3 The Rules incorporate those requirements of the *International Convention for the Safety of Life at Sea, 1974* as amended *Chapter X - Safety measures for high-speed craft* - Safety Measures for High Speed Craft (*International Code of Safety for High Speed Craft*) hereinafter referred to as the HSC code, as applicable to the classification of such craft.

1.1.4 Requirements for craft which are not required to comply with the IMO Code for High Speed Craft are given at the end of each Chapter. Requirements for service craft, yachts of 24 m or greater and other craft types have been included in these requirements. For the purposes of *Pt 9 General Requirements for Machinery* to *Pt 16 Control and Electrical Engineering*, small craft are service craft of less than 24 m in length.

1.1.5 Special requirements are included for main and auxiliary machinery, pumping and piping, electrical and control engineering and fire extinction for yachts.

1.1.6 These Rules are applicable to machinery systems burning distillate fuels which do not require to be heated.

1.2 General

1.2.1 The units and formulae used in the Rules are in SI Units.

1.2.2 It is the responsibility of the Shipbuilder as main contractor to ensure that the information required is prepared and submitted.

1.2.3 Where the craft is defined as a Passenger (B) Craft (*see Pt 1, Ch 2, 3 Character of classification and class notations*), sufficient redundancy is to be provided such that in the event of damage to any part of a main propulsion drive system, the craft is able to maintain sufficient seaway.

1.2.4 Sufficient astern power is to be provided to maintain control of the craft in all normal circumstances.

1.2.5 The main propulsion machinery will be approved for the maximum continuous power, and associated shaft speed, required to achieve the maximum craft velocity at the certified maximum operational weight in smooth water.

1.2.6 Main propulsion machinery will be considered for operation at a higher power rating than the classification rating for short time intervals (referred to as short term high power operation) in conjunction with the intended operation service profile.

1.2.7 Provision shall be made to facilitate cleaning, inspection and maintenance of main propulsion and auxiliary machinery including boilers and pressure vessels.

1.3 Deviations from the Rules

1.3.1 Any proposal to deviate from the requirements of the Rules will be specially considered.

1.4 Fuel flash point

1.4.1 The flash point (closed-cup test) of fuel oil is in general to be not less than 60°C. For emergency generator engines a flash point of not less than 43°C is permissible.

1.4.2 Fuel oil with a flash point lower than 60°C may be used where it can be shown that the temperature of the fuel oil will always be not less than 10°C below its flash point.

1.4.3 The use of fuel with a flash point below 43°C is not recommended. However, fuel with a lower flash point, but not lower than 35°C, may be used in gas turbines only, subject to compliance with the provisions in *Pt 9, Ch 1, 4 Operating conditions*.

1.5 Exhaust

1.5.1 Where the surface temperature of the exhaust pipes and silencer may exceed 220°C, they are to be water cooled or efficiently lagged to minimise the risk of fire and to prevent damage by heat. Where lagging covering the exhaust piping system including flanges is oil-absorbing or may permit penetration of oil, the lagging is to be encased in sheet metal or equivalent. In locations where the Surveyor is satisfied that oil impingement could not occur, the lagging need not be encased.

1.6 Bearings

1.6.1 Roller element bearings are to have an L10 design life of at least 30 000 hours, based upon the design operating conditions, including short term high power operation. An L10 design life of less than 30 000 hours would be accepted, provided it is proposed in conjunction with the manufacturer's design/maintenance manual.

1.7 Vibration of shaft systems

1.7.1 The Shipbuilders are to ensure that the systems are free from excessive vibrations, excessive bearing reactions and excessive bending moments under all design operating conditions.

1.7.2 Where changes are subsequently made to a dynamic system which has been approved by Lloyd's Register (hereinafter referred to as 'LR'), e.g. machining a shaft, fitting a propeller of a different design to the working propeller or fitting a different flexible coupling, full details of the changes are to be advised. Revised calculations may be required to be submitted.

1.7.3 Where there is experience of previous similar systems which have been approved, full details of these installations may be submitted for consideration in lieu of calculations.

■ *Section 2* Particulars to be submitted

2.1 Submission of information

2.1.1 At least three copies of plans, information and specifications as listed are to be submitted before commencement of manufacture.

2.2 Plans

2.2.1 Plans are to indicate clearly the scantlings and materials of construction. Any design alteration to the plan is to be resubmitted for approval, indicating clearly the alteration.

2.2.2 Individual Chapters also list plans to be submitted for specific machinery systems or components.

2.2.3 Where machinery system components have been approved under LR's Type Approval System or Machinery General Design Appraisal for the proposed design conditions or service, plans of the component will not be required to be submitted for individual newbuildings. Full details of the components are to be advised.

2.2.4 Plans showing the arrangement of resiliently mounted machinery are to indicate the number, position, type, and design of mounts.

2.2.5 The plans of arrangement of resin chocks for machinery requiring accurate alignment are to be submitted.

2.3 Calculations and specifications

2.3.1 Relevant data covering the following topics is to be submitted.

2.3.2 **Service Profile**. The machinery power/speed operational envelope indicating all the intended operational points applicable to the class notation, and any short term high power operation.

2.3.3 **Classification rating**:

(a) The following operational parameters are to be taken, using the design conditions for the intended Class Notation:

- Total barometric pressure, in bar.
- Temperature of engine room, or suction air, in ^{o}C.
- The relative humidity, in per cent.
- Temperature of sea water, or charge air coolant inlet, in ^{o}C.

(b) For unrestricted service, the following operational parameters ambient reference conditions are to be taken:

- Total barometric pressure, at 1000mb.
- Temperature of engine room or suction air, at 45^{o}C.
- Relative humidity, at 60 per cent.
- Temperature of sea water or charge air coolant inlet, at 32^{o}C.

2.3.4 **Short term high power operation**. Where the propulsion machinery is being considered for short term high power operation, full details of the power, speed and time intervals together with fatigue endurance calculations, and documentary evidence indicating the suitability of the component design under these conditions and for the intended class notation are required. The following are to be considered; prime mover, gearbox, flexible coupling, vibration dampers, shafting and propeller.

(a) The accrued number of load cycles and the percentage component overload are to be those recommended by the designers.
(b) Excessive overload may require the interval between surveys to be reduced.
(c) Machinery is to be maintained in accordance with the manufacturers' requirements.

2.3.5 **Damper and Flexible Coupling characteristics**. Documentary evidence that the characteristics have been verified.

2.3.6 **Machinery Fastening**.

(a) Documentary evidence and calculations indicating that machinery is securely mounted for the accelerations to be expected during service.
(b) Calculations that mountings of large masses such as main engines, auxiliary engines, lift fans and electrical equipment can withstand the design collision acceleration according to *Pt 9, Ch 1, 5.2 Collision load 5.2.1* without fracturing.
(c) Natural frequency calculation of resilient mounted machinery.
(d) For non-metallic machinery chocks:
    (i) Resin type.
    (ii) The effective area and minimum thickness of the chocks.
    (iii) The total deadweight loading of machinery.
    (iv) The thrust load, where applicable, that will be applied to the chocked item.
    (v) The loading to be applied to the holding-down bolts.
    (vi) The material of the holding-down bolts.
    (vii) The number, thread size, and waisted shank diameter (where applicable) of the holding-down bolts.

2.3.7 **Manuals**. The operation and maintenance manuals.

2.3.8 **Failure Mode and Effect Analysis**. Where required for high speed craft, an FMEA is to be carried out covering the following systems:

(a) Main and auxiliary machinery systems, and their controls.
(b) Steering systems.
(c) Electrical systems.

2.3.9 **Fatigue Strength Analysis**. Where undertaken as an alternative to the requirements of the individual Chapters, fatigue strength analysis of components indicating a factor of safety of 1,5 at the design loads based on a suitable fatigue failure criteria. The effects of stress concentrations, material properties and operating environment are to be taken into account.

■ *Section 3*
Certification of materials

3.1 Materials of construction

3.1.1 Materials used in the construction are to be in accordance with, or shown to be equivalent to, *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials). Details of all materials included and not included in the Rules for Materials are to be forwarded as soon as possible (preferably at the design concept stage) and before commencement of manufacture.

3.1.2 Materials used in the construction of machinery and its installation are not to contain asbestos.

■ *Section 4*
Operating conditions

4.1 Availability for operation

4.1.1 The design and arrangement is to be such that the machinery can be started and controlled on board, without external aid.

4.1.2 Machinery is to be capable of operating at defined power ratings with a range of fuel grades specified by the engine, boiler or machinery manufacturer and agreed by the Owner/Operator.

4.1.3 Machinery is to be capable of operating satisfactorily in accordance with the manufacturer's stated operating conditions within an operational profile specified for the ship by the Owner/Operator and agreed by the manufacturer/system designer.

4.2 Inclinations of the craft

4.2.1 The main and auxiliary machinery is to be designed and installed such that it operates satisfactorily under the conditions as shown in *Table 1.4.1 Inclinations*.

Table 1.4.1 Inclinations

Installations, components	Angle of inclination, degrees, *see* Note 1			
	Athwartship		Fore-and-aft	
	Static	Dynamic	Static	Dynamic
Main and auxiliary machinery essential to the propulsion and safety of the craft	15	22,5	5 *see* Note 2	7,5
Emergency machinery and equipment fitted in accordance with Statutory Requirements	22,5	22,5	10	10

Note 1. Athwartships and fore-and-aft inclination may occur simultaneously.

Note 2. Where the length of the craft exceeds 100 m, the fore-and-aft static angle of inclination may be taken as: $\frac{500}{L_{WL}}$ *degrees*

where

L_{WL} = craft waterline length, in metres

4.2.2 The arrangements for lubricating bearings and for draining the crankcase and other oil sumps of main and auxiliary engines, gearcases, electric generators, motors, and other running machinery are to be so designed that lubrication will remain efficient with the craft inclined under the conditions as shown in *Table 1.4.1 Inclinations*.

4.2.3 Deviations from these conditions may be accepted taking into consideration type and size of the craft and the class notation. The Shipbuilder is to ensure that the main and auxiliary machinery is capable of operating at the proposed angles of inclination.

4.3 Power ratings

4.3.1 In the Chapters where the dimensions of any particular component are determined from shaft power, *P*, in kW (*H*, in shp), and revolutions per minute, *R*, the values to be used are to be derived from the following:

- For main propelling machinery, the maximum shaft power and corresponding revolutions per minute giving the maximum torque for which the machinery is to be classed.
- For auxiliary machinery, the maximum continuous shaft power and corresponding revolutions per minute which will be used in service.

4.4 Ambient reference conditions

4.4.1 The rating for classification purposes of main and essential auxiliary machinery intended for installation in sea-going ships to be classed for unrestricted (geographical) service is to be based on a total barometric pressure of 1000 mb, an engine room ambient temperature or suction air temperature of 45°C, a relative humidity of 60 per cent and sea-water temperature or, where applicable, the temperature of the charge air coolant at the inlet of 32°C. The equipment manufacturer is not expected to provide simulated ambient reference conditions at a test bed.

4.4.2 In the case of a ship to be classed for restricted service, the rating is to be suitable for the temperature conditions associated with the geographical limits of the restricted service, *see Pt 1, Ch 2, 3.5 Service area restriction notations*.

4.5 Ambient operating conditions

4.5.1 Main and essential auxiliary machinery and equipment is to be capable of operating satisfactorily under the conditions shown in *Table 1.4.2 Ambient operating conditions*.

Table 1.4.2 Ambient operating conditions

Air		
Installations, Components	Location, arrangement	Temperature range (°C)
Machinery and electrical installations	In enclosed spaces	0 to +45, *see* Note 1
	On machinery components, boilers. In spaces subject to higher and lower temperatures	According to specific local conditions, *see* Note 2
	On the open deck	–25 to +45, *see* Note 1
Water		
Coolant		Temperature (°C)

Sea-water or charge air coolant inlet to charge air cooler	-2 to +32, *see* Notes 1 and 3
Note 1. For ships intended to be classed for restricted service, a deviation from the temperatures stated may be considered.	
Note 2. Details of local environmental conditions are stated in Annex B of IEC 60092: *Electrical installations in ships – Part 101: Definitions and general requirements*.	
Note 3. Charge air cooling arrangements utilising re-circulated cooling to maintain temperatures in a different range are accepted where the machinery and equipment operation is not degraded with a primary supply of cooling in the temperature range stated in this Table.	

4.5.2 Where it is intended to allow for operation in ambient temperatures outside those shown in *Table 1.4.2 Ambient operating conditions*, the permissible temperatures and associated periods of time are to be specified and details are to be submitted for consideration. Propelling and essential auxiliary machinery, *see Pt 1, Ch 2, 3.10 Application notes 3.10.1*, is to retain a continuous level of functional capability under these conditions and any level of degraded performance is to be defined. Operation under these circumstances is not to be the cause of damage to equipment in the system and is additionally to be acceptable to the National Authority of the country in which the craft is to be registered

4.6 Power conditions for generator sets

4.6.1 Auxiliary engines coupled to electrical generators are to be capable under service conditions of developing continuously the power to drive the generators at full rated output (kW) and in the case of reciprocating internal combustion engines and gas turbines, of developing for a short period (15 minutes) an overload power of not less than 10 per cent, *see Pt 16, Ch 2, 9.2 Rating* In the case of reciprocating internal combustion engines, they are to be tested at works trials as required by Pt 10, Ch 1, *Table 1.11.1 Scope of works trials for engines*.

4.6.2 Engine builders are to satisfy the Surveyors by tests on individual engines that the above requirements, as applicable, can be complied with, due account being taken of the difference between the temperatures under test conditions and those referred to in *Pt 9, Ch 1, 4.4 Ambient reference conditions*. Alternatively, where it is not practicable to test the engine/generator set as a unit, type tests (e.g. against a brake) representing a particular size and range of engines may be accepted. With engines and gas turbines any fuel stop fitted is to be set to permit the short period overload power of not less than 10 per cent above full rated output (kW) being developed.

4.7 Astern power

4.7.1 In order to maintain sufficient manoeuvrability and secure control of the ship in all normal circumstances, the main propulsion machinery is to be capable of reversing the direction of thrust so as to bring the ship to rest from the maximum service speed. The main propulsion machinery is to be capable of maintaining in free route astern at least 70 per cent of the ahead revolutions corresponding to the maximum continuous ahead power for which the vessel is classed.

4.8 Machinery interlocks

4.8.1 Interlocks are to be provided to prevent any operation of engines or turbines under conditions that could cause a hazard to the machinery and personnel. These are to include ‘turning gear engaged’, ‘low lubricating oil pressure’, where oil pressure is essential for the prevention of damage during start up, ‘shaft brake engaged’ and where machinery is not available due to maintenance or repairs. The interlock system is to be arranged to be ‘fail safe’.

4.8.2 Where machinery is provided with manual turning gear, warning devices or notices may be provided as an alternative to interlocks as required by *Pt 9, Ch 1, 4.8 Machinery interlocks 4.8.1*.

Section 5
Securing of machinery

5.1 Fastenings

5.1.1 Bedplates, thrust seatings and other fastenings are to be of robust construction. The machinery is to be securely fixed to the craft's structure, such that the arrangement is sufficient to restrain the dynamic forces arising from vertical and horizontal acceleration appropriate to the intended service.

5.2 Collision load

5.2.1 Unless an accurate analysis of the collision load is submitted and found acceptable by LR, the collision load is to be determined from:

$$\mathrm{g(collision)} = 1,2\frac{P_{\mathrm{coll}}}{\Delta\,\mathrm{g}}$$

where the load P_{coll} is taken as the lesser of:

$$P_{\text{coll}} = 460\left(MC_{\mathrm{L}}\right)^{\frac{2}{3}}\left(EC_{\mathrm{H}}\right)^{\frac{1}{3}}\ \mathrm{kN}$$

$$P_{\text{coll}} = 9000\,MC_{\mathrm{L}}\left[C_{\mathrm{H}}(T+2)\right]^{\frac{1}{2}}\ \mathrm{kN}$$

where

C_{H} = a factor given in *Table 1.5.1 Factor C_H*

C_{L} = $\dfrac{\left(165 + L_{\mathrm{WL}}\right)}{245}\left(\dfrac{L_{\mathrm{WL}}}{80}\right)^{0,4}$

D = craft depth, in metres, from the underside of keel amidships to the top of effective hull girder

E = $0,5\,\Delta\,V^2$ kNm

H_{T} = minimum height, in metres, from tunnel or wet-deck bottom to the top of effective hull girder for catamarans and surface effect ships

= D for air cushion vehicles

L_{WL} = craft waterline length, in metres

M = 1,3 for high tensile steel

= 1,0 for aluminium alloy

= 0,95 for mild steel

= 0,8 for fibre reinforced plastics

T = buoyancy tank clearance to skirt tip, in metres, (negative) for ACVs

= lifted clearance from keel to water surface, in metres, (negative) for hydrofoils

= craft draught to the underside of keel amidships, in metres, for all other craft

V = operational speed of craft, in m/s

g = gravitational acceleration = 9,806 m/s^2

Δ = craft displacement, to be taken as the mean of the lightweight and maximum operational weight, in tonnes

Table 1.5.1 Factor C_H

Factor C_H	Catamarans, SES	Mono-hulls, H'foils	ACVs
C_H	$\frac{T+2+f(D/2)}{2D}$	$\frac{T+2+f(D/2)}{2D}$	$\frac{f}{4}$
where			
f = 0 for	$T + 2 < D - H_T$	$T + 2 < D$	-
f = 1 for	$D > T + 2 \geq D - H_T$	$T + 2 \geq D$	$H_T > 2$
f = 2 for	$T + 2 \geq DM$	-	$H_T \leq 2$

5.3 Resilient mounts

5.3.1 The dynamic angles of inclination in *Table 1.4.1 Inclinations* may be exceeded in certain circumstances dependent upon ship type and operation. The Shipbuilder is, therefore, to ensure that the vibration levels of flexible pipe connections, shaft couplings and mounts remain within the limits specified by the component manufacturer for the following conditions:

(a) Maximum dynamic inclinations to be expected during service;
(b) Start-stop operation; and
(c) The natural frequencies of the system.

Due account is to be taken of any creep that may be inherent in the mount.

5.3.2 For equipment of installed power greater than 375 kW, *see Pt 16, Ch 2, 1.6 Definitions 1.6.10*(b), a calculation report is to be submitted to demonstrate that the requirements of *Pt 9, Ch 1, 5.3 Resilient mounts 5.3.2* are met. The calculation report is to include as a minimum:

(a) A plan showing the arrangement of the machinery including mounts, exhaust bellows, and flexible couplings and pipe connections, as applicable; and
(b) Maximum allowable loads and deflections and any appropriate type approval documentation for each flexible element (resilient mounts, exhaust gas bellows, flexible couplings and any other applicable flexible pipe connections) for the conditions identified in *Pt 9, Ch 1, 5.3 Resilient mounts 5.3.2*; and
(c) Calculations including natural frequencies and maximum expected loads and deflections of each flexible element (resilient mounts, exhaust gas bellows, flexible couplings and any other applicable flexible pipe connections) for the conditions identified in *Pt 9, Ch 1, 5.3 Resilient mounts 5.3.2*.

5.3.3 Chocks are to be fitted, together with positive means to ensure that manufacturers' limits for lateral or vertical motion are not exceeded. Where resilient mounts are approved for collision loading, *see Pt 9, Ch 1, 5.2 Collision load*, then the extent of any additional chocking that may be required will be specially considered. Suitable means are to be provided to accommodate the propeller thrust.

5.3.4 Mounts are to be shielded from the possible detrimental effects of oil and, where appropriate, paint and other contaminants.

5.3.5 Shafting, piping connections and electrical cable connections are to be provided with sufficient flexibility to accommodate expected movements. Particular attention should be paid to exhaust bellows and the effectiveness of flexible couplings.

5.4 Resin chocks

5.4.1 Synthetic resin compounds used as materials for chocks under machinery components for which alignment is critical, e.g. main engine, gearbox and auxiliary installations where the engine and generator do not share a common baseplate, are to be of a type approved by LR.

5.4.2 The resin chock materials referred to in *Pt 9, Ch 1, 5.4 Resin chocks 5.4.1* are to be tested in accordance with *Ch 14, 2.11 Machinery chocking compounds (resin chocks)* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2021*.

5.4.3 Materials for chocks are to be approved for the maximum service temperature that the chock will experience.

5.4.4 The use of resin for chocking gas turbine casings or similar high temperature applications will be specially considered.

Section 6
Requirements for craft which are not required to comply with the HSC Code

6.1 Plans and particulars

6.1.1 At least three copies of the following plans are to be submitted for approval at the earliest opportunity:

- Crankshaft including details of the material specification.
- Gearing including details of the material specification.
- Arrangement and details of the propulsion shafting, couplings and bearing disposition etc.
- Propeller where the diameter exceeds 1 m.
- Diagrammatic arrangements of the exhaust systems indicating the materials, methods of cooling, and if water spray is injected, the method of draining.
- Starting air system and receivers.
- Diagrammatic arrangements of pumping and piping systems including the air and sounding pipes for the tanks.
- Diagrammatic arrangements of bilge and fire water pumps and piping for craft having a Rules length of 12 m and over and which are subdivided into watertight compartments.
- Diagrammatic arrangement of fuel oil piping.
- Construction arrangements of separate fuel oil tanks having a capacity exceeding 500 litres (250 litres for small craft).
- Electrical equipment as detailed in *Pt 16, Ch 2 Electrical Engineering*.
- Steering gear machinery and hydraulic circuit diagram if applicable.
- Fire extinction equipment as detailed in *Pt 17 Fire Protection, Detection and Extinction*.
- Safety plan showing the position of all fire prevention controls, fixed and loose equipment, and portable extinguishers, *see Pt 17, Ch 1 Fire Protection, Detection and Extinction – General* to *Pt 17, Ch 4 System and Equipment Specifications*.
- Control circuits and alarm points as detailed in *Pt 16, Ch 1 Control Engineering Systems*.

6.1.2 The following particulars are to be submitted with the plans of crankshaft, gearbox or shafting as applicable:

- Name of manufacturer.
- Type designation.
- Particulars of engine cycle.
- Number of cylinders and vee angle where applicable.
- Maximum combustion pressure and mean indicated pressure.
- Span of bearings adjacent to a crank measured from centreline of the bearing to the centreline of the adjacent bearing.
- Proposed shaft power (kW) and revolutions per minute of the engine at each operating condition.
- Gear box reduction ratio.
- For engines over 500 kW, *see Pt 10, Ch 1, 2 Materials and components*.

6.1.3 Where machinery system components or equipment have been approved under LR's Type Approval System or Machinery General Design Appraisal for the proposed design conditions or intended service, full details of the components should be advised to enable the validity of the approval to be checked. In cases where valid approvals are confirmed, plans are not required to be submitted for approval for individual craft.

6.2 Calculations

6.2.1 Design calculations are to be submitted for the following systems and conditions:

(a) Direct calculation for design strength of machinery supports, such as engine mountings, on craft subjected to high accelerations, *see Pt 9, Ch 1, 5 Securing of machinery*.
(b) Calculations of torsional vibrations for main engines where the power exceeds 500 kW and for auxiliary engines for essential services where the power exceeds 110 kW.

6.3 Certification of materials

6.3.1 The requirements of *Pt 9, Ch 1, 3.1 Materials of construction* apply to all types of craft.

6.3.2 Where no provision is made in these Rules, materials may be accepted provided that they comply with an approved specification and such tests as may be considered necessary by the Surveyor.

6.3.3 The requirements for materials for machinery components are indicated in the relevant Part or Chapter of the Rules.

6.4 Operating conditions

6.4.1 The requirements of *Pt 9, Ch 1, 4.2 Inclinations of the craft* do not apply to yachts or service craft less than 24 m.

6.4.2 For patrol craft and high speed craft of 24 m or greater, the main and auxiliary machinery is to be designed to operate under the conditions defined in *Pt 9, Ch 1, 4 Operating conditions* and *Pt 9, Ch 1, 5 Securing of machinery*.

6.4.3 If operation under the required accelerations cannot be demonstrated on trials, alternative documentary evidence is to be presented to confirm that the machinery is capable of operating under such conditions.

6.4.4 Additional trials or conditions may be imposed to prove the machinery as considered necessary.

6.5 Securing of machinery

6.5.1 The requirements of *Pt 9, Ch 1, 5.1 Fastenings*, *Pt 9, Ch 1, 5.3 Resilient mounts* and *Pt 9, Ch 1, 5.4 Resin chocks* apply.

6.5.2 Engines are to be installed so as to permit easy access to fittings, such as lubricating oil connections, bilge suctions and sea cocks.

6.5.3 Where the hull is constructed of FRP, wood or composites, and the hull surfaces are not adequately protected against oil contamination, drip trays are to be fitted under those parts of the engine and gearbox where leakage of fuel oil or lubricating oil might occur. Means are to be provided for removing any leakage easily.

6.5.4 Where resilient mounts are fitted, the name of the manufacturer and details of the type of mounting are to be indicated on the plan of the shafting.

6.5.5 Where inclinations beyond those defined in 4.2 might be experienced, such as yacht roll over, means are to be provided to prevent machinery becoming dislodged.

6.5.6 Satisfactory arrangements are to be made to transmit the propulsion thrust into the craft structure.

6.6 Ventilation of machinery spaces

6.6.1 For yachts and service craft of less than 24 m the ventilation of the machinery space is to be adequate for all conditions of the operation of the machinery and in no case is to be less than that required by the engine manufacturer.

6.6.2 The engine compartment is to be provided with inlet and outlet ventilating ducts. One or more inlet ducts are to extend down to a suitable low level.

6.6.3 Outlet ducts are to be connected near or at the top of the compartment and are to be arranged for natural or mechanical extraction as necessary.

6.6.4 Consideration will be given to equivalent alternative arrangements provided full details are submitted before construction is commenced.

Surveys During Construction, Installation and Sea Trials

■ *Section 1*
General requirements

1.1 Surveys during construction

1.1.1 Unless an alternative approach for product assurance has been approved by LR (*see Pt 9, Ch 2, 1.3 Alternative approach for product assurance*), all items of machinery and equipment in ships built under Special Survey are to be surveyed at the manufacturer's works. The Surveyor is to be satisfied that the workmanship is of a suitable standard and that the components are suitable for the intended purpose and duty.

1.1.2 Lloyds Register's (hereinafter referred to as LR) requirements for the conditions of manufacture, survey and certification of materials used for the production of forged steel and castings used in the production of components are given in the, *Rules for the Manufacture, Testing and Certification of Materials* (commonly referred to as the Rules for Materials).

1.2 Miscellaneous surveys

1.2.1 Resilient mounts are to be installed under survey and the machinery tested under full working conditions.

1.2.2 Alignment of machinery is to be checked after the first six months of operation.

1.3 Alternative approach for product assurance

1.3.1 LR will be prepared to give consideration to the adoption of an approach for pruduct assurance, utilising regular and systematic audits of an organisation's arrangements for assuring product quality as an alternative to the direct survey of individual items.

1.3.2 Alternative approaches for product assurance are to be approved by LR. In order to obtain approval, the requirements of *Pt 5, Ch 1, 6 Quality Assurance Scheme for Machinery* of the Rules for Ships or the Rules for Materials, *Ch 1, 2.4 Materials Quality Scheme*, are to be complied with. Proposals for equivalent approaches are to be submitted for consideration.

■ *Section 2*
Gas turbines

2.1 Dynamic balancing

2.1.1 All rotors as finished-bladed and complete with half-coupling are to be dynamically balanced in accordance with the manufacturer's specification in a machine of sensitivity appropriate to the size of rotor.

2.2 Hydraulic testing

2.2.1 All casings are to be tested to a hydraulic pressure equal to 1,5 times the highest pressure in the casing during normal operation, or 1,5 times the pressure during starting, whichever is the higher. For test purposes, if necessary, the casings may be subdivided with temporary diaphragms for distribution of test pressure.

2.2.2 Where hydraulic tests cannot be carried out on the casing, alternative proposals will be considered.

2.2.3 Intercoolers and heat exchangers are to be tested to 1,5 times the maximum working pressure on each side separately.

2.3 Overspeed tests

2.3.1 Before installation, the gas turbine is to be tested for five minutes at five per cent above the nominal setting of the overspeed protective device, or 15 per cent above the maximum design speed, whichever is the higher.

2.3.2 Where it is impracticable to overspeed the complete installation, each rotor, completely bladed and with all relevant parts such as half-couplings, is to be overspeed-tested individually at the appropriate speed.

■ *Section 3* Gearing

3.1 Construction and welding

3.1.1 Where castings are used for wheel centres, any radial slots in the periphery are to be fitted with permanent chocks before shrinking-on the rim.

3.1.2 Where welded construction is used for the manufacture of wheels and gearcases, welding is to be in accordance with the requirements specified in *Ch 13 Requirements for Welded Construction* of the Rules for Materials.

3.1.3 Welded constructions are to be stress relief heat treated on completion of welding.

3.1.4 Bolted attachments within the gear case are to be secured by locking wire or equivalent means.

3.2 Accuracy of gear cutting

3.2.1 The machining accuracy (Q grade) of pinions and wheels is to be demonstrated. For this purpose records of measurements are to be available for review.

3.3 Non-destructive testing

3.3.1 Magnetic particle or liquid penetrant testing is to be carried out on the teeth of all surface hardened forgings. This examination may also be requested on the finished machined teeth of through hardened gear forgings.

3.3.2 The manufacturer is to carry out an ultrasonic examination of all forgings where the finished diameter of the surfaces, where teeth will be cut, is in excess of 200 mm, and is to provide LR with a signed statement that such inspection has not revealed any significant internal defects.

3.3.3 On gear forgings where the teeth have been surface hardened, additional test pieces may be required to be processed with the forgings and subsequently sectioned to determine the depth of the hardened zone. These tests are to be carried out at the discretion of the Surveyor, and for induction or carburised gearing the depth of the hardened zone is to be in accordance with the approved specification. For nitrided gearing, the full depth of the hardened zone, i.e. depth to core hardness, is to be not less than 0,5 mm and the hardness at a depth of 0,25 mm is to be not less than 500 Hv.

3.4 Dynamic balancing

3.4.1 All rotating elements such as pinion and wheel shaft assemblies and coupling parts, are to be appropriately balanced.

3.4.2 The permissible residual unbalance, *U*, is defined as follows:

$$U = \frac{60\mathrm{m}}{R} \times 10^3 gmm\, for\ R \leq 3000$$

$$U = \frac{24m}{R} \times 10^3\ gmm\, for\ R > 3000$$

where

m = mass of rotating element, in kg

R = maximum service rev/min of the rotating element

3.4.3 Where the size or geometry of a rotating element precludes measurement of the residual unbalance a full speed running test of the assembled gear unit at the manufacturer's works will normally be required to demonstrate satisfactory operation.

3.5 Meshing tests

3.5.1 Initially, meshing gears are to be carefully matched on the basis of the accuracy measurements taken. The alignment is to be demonstrated in the workshop by meshing in the gearbox without oil clearance in the bearings. Meshing is to be carried out with the gears locating in their light load positions and a load sufficient to overcome pinion weight and axial movement is to be imposed.

3.5.2 The gears are to be suitably coated to demonstrate the contact marking. The thickness of the coating to determine the contact marking is not to exceed 0,005 mm. The marking is to reflect the accuracy grade specified and end relief, crowning or helix correction, where these have been applied.

3.5.3 For gears without crowning or helix correction the marking is to be not less than shown in *Table 2.3.1 No load tooth contact marking*.

Table 2.3.1 No load tooth contact marking

ISO accuracy grade	Contact marking area
Q ≤ 5	50% b x 40% h_w + 40% b x 20% h_w
Q ≥ 6	35% b x 40% h_w + 35% b x 20% h_w
Note 1. Where b is the face width and h_w is the working tooth depth. Note 2. For spur gears, the values of h_w should be increased by a further 10%.	

3.5.4 Where allowance has been given for end relief, crowning or helix correction, the normal shop meshing tests are to be supplemented by tooth alignment traces or other approved means to demonstrate the effectiveness of such modifications.

3.5.5 For gears with crowning, or helix correction the marking is to correspond to the designed no load contact pattern.

3.5.6 A permanent record is to be made of the meshing contact for purpose of checking the alignment when installed on board the craft.

3.5.7 The full load tooth contact marking is to be not less than shown in *Table 2.3.2 Full load tooth contact marking*.

Table 2.3.2 Full load tooth contact marking

ISO accuracy grade	Contact marking area
Q ≤ 5	60% b x 70% h_w + 30% b x 50% h_w
Q ≥ 6	45% b x 60% h_w + 35% b x 40% h_w
Note 1. Where b is the face width and h_w is the working tooth depth. Note 2. For spur gears, the values of h_w should be increased by a further 10%.	

3.5.8 Where, due to the compactness of the gear unit, meshing tests of individual units cannot be verified visually, consideration may be given to the gear manufacturer providing suitable evidence that the design meshing condition has been attained on units of the same design.

3.5.9 The normal backlash between any pair of gears should not be less than:

$$\frac{a\,\alpha_{\text{n}}}{90000} + 0,1\text{ mm}$$

where

α_n = normal pressure angle, in degrees

a = centre distance, in mm

■ *Section 4* Shafting systems

4.1 Construction and installation

4.1.1 Boring of the sternframe, fitting of the sterntube and bearings and aligning the shafting are to be carried out to a formal traceable procedure.

4.1.2 Before boring the sternframe the structure should be generally complete to the upper deck and to the engine-room forward bulkhead.

■ *Section 5* Propellers

5.1 Construction and welding

5.1.1 Castings are to be examined at the manufacturer's works.

5.1.2 All finished propellers are to be examined for material defects and finish, and measured for dimensional accuracy of diameter and pitch. Propeller repairs by welding, where proposed, are to be in accordance with the requirements of *Ch 9, 1 Castings for propellers*.

5.2 Shop tests of keyless propellers

5.2.1 The bedding of the propeller with the shaft is to be demonstrated. Sufficient time is to be allowed for the temperature of the components to equalise before bedding. Alternative means for demonstrating the bedding of the propeller will be considered.

5.2.2 Means are to be provided to indicate the relative axial position of the propeller boss on the shaft taper.

5.3 Shop tests of controllable pitch propellers

5.3.1 The components of controllable pitch propellers are also subject to material tests, as in the case of solid propellers.

5.3.2 Examination of all the major components including dimensional checks, hydraulic pressure testing of the hub and cone assembly and the oil distribution box, where fitted, together with a full shop trial of the completed controllable pitch propeller assembly, is to be carried out.

5.4 Final fitting of keyless propellers

5.4.1 After verifying that the propeller and shaft are at the same temperature and the mating surfaces are clean and free from oil or grease, the propeller is to be fitted on the shaft under survey. The propeller nut is to be securely locked to the shaft.

5.4.2 Permanent reference marks are to be made on the propeller boss nut and shaft to indicate angular and axial positioning of the propeller. Care is to be taken in marking the inboard end of the shaft taper to minimise stress raising effects.

5.4.3 The outside of the propeller boss is to be hard stamped with the following details:

- For oil injection method of fitting, the start point load, in Newtons, and the axial pull-up at 0°C and 35°C, in mm.

- For the dry fitting method, the push-up load at 0°C and 35°C, in Newtons.

5.4.4 A copy of the fitting curve relative to temperature and means for determining any subsequent movement of the propeller are to be placed on board.

5.5 Final fitting of keyed propellers

5.5.1 The fit of the screwshaft cone to both the working and any spare propeller is to be carried out under survey. Generally, a satisfactory fit for keyed type propellers should show a light, overall marking of the cone surface with a tendency towards heavier marking in way of the larger diameter of the cone face. The final fit to cone should be made with the key in place.

■ *Section 6* Water jet units

6.1 Construction and welding

6.1.1 The following components are to be inspected at the manufacturer's works:

- Steering nozzle.
- Reverse bucket.
- Stator impeller.
- Integral bearing.

6.1.2 Welded construction is to be in accordance with the requirements specified in *Ch 13 Requirements for Welded Construction* of the Rules for Materials.

6.1.3 Welded components are to comply with the requirements of *Pt 15, Ch 4 Pressure Plant* and be subject to stress relief heat treatment upon completion. Where an impeller has welded blades, non-destructive testing is to be carried out to an approved procedure.

6.2 Testing

6.2.1 Testing of the first installation of a new type of water jet unit is required and is to demonstrate the adequacy of the steering and reversing mechanisms during the most arduous manoeuvres.

6.2.2 Upon completion, the impeller assembly is to be suitably balanced in accordance with ISO 940 Grade G6,3 or an equivalent Standard.

■ *Section 7* Thrusters

7.1 Azimuth thrusters

7.1.1 The performance specified for the craft is to be demonstrated.

7.1.2 The actual values of steering torque are to be verified during sea trials to confirm that the design maximum dynamic duty torque has not been exceeded.

7.2 Tunnel thrusters

7.2.1 It is to be demonstrated that the thruster unit meets the specified performance.

Section 8
Steering systems

8.1 Construction

8.1.1 The requirements of the Rules relating to the testing of Class I pressure vessels, piping and related fittings including hydraulic testing apply.

8.2 Type testing

8.2.1 Each type of power unit pump is to be subjected to a type test. The type test is to be for a duration of not less than 100 hours, the test arrangements are to be such that the pump may run in idling conditions, and at maximum delivery capacity at maximum working pressure. During the test, idling periods are to be alternated with periods at maximum delivery capacity at maximum working pressure. The passage from one condition to another should occur at least as quickly as on board. During the whole test no abnormal heating, excessive vibration or other irregularities are permitted. After the test, the pump is to be opened out and inspected. Type tests may be waived for a power unit which has been proven to be reliable in marine service.

8.3 Testing

8.3.1 After installation on board the craft the steering unit is to be subjected to the applicable hydrostatic and running tests.

8.3.2 The steering system is to be demonstrated to show that the requirements of the Rules have been met. The trial is to include the operation of the following:

(a) The steering system, including demonstration of the functional performances.
(b) The steering power units, including transfer between steering power units.
(c) The isolation of one power actuating system, checking the time for regaining steering capability.
(d) The hydraulic fluid recharging system (may be effected at the dockside).
(e) The emergency power supply.
(f) The steering controls, including transfer of control and local control.
(g) The means of communication between the steering compartment and the wheelhouse, also the engine room, if applicable (may be effected at the dockside).
(h) The alarms and indicators (may be effected at the dockside).
(i) Where the steering system is designed to avoid hydraulic locking this feature is to be demonstrated (may be effected at the dockside).

Section 9
Sea trials

9.1 Sea trials requirements

9.1.1 Sea trials are to be of sufficient duration and carried out under normal operating conditions applicable to the intended class notation. Individual Chapters give specific requirements.

9.2 Programme

9.2.1 Sea trials are to include the demonstration of:

(a) The adequacy of the starting arrangements of the main engines, auxiliary systems and emergency generators.
(b) The effectiveness of the steering gear control systems.
(c) Manoeuvring, to include:

- starting;
- normal and emergency stopping;
- reversing;

- governor testing;
- safety devices, and associated indicators and alarms.

(d) The redundancy arrangements for Category B craft.

(e) Tooth contact markings in geared installations using a recognised technique. The marking is to be as detailed in *Pt 9, Ch 2, 3.5 Meshing tests*.

(f) For controllable pitch propellers, the pitch setting under failure conditions.

9.2.2 Main propulsion systems are to undergo tests to demonstrate the astern response characteristics. The tests are to be carried out over at least the manoeuvring range of the propulsion system and from all control positions. A test plan is to be provided by the yard and accepted by the Surveyor. If specific operational characteristics have been defined by the manufacturer, then these are to be included in the test plan.

9.2.3 Specific requirements for shipboard trials of reciprocating internal combustion engines are provided in *Pt 10, Ch 1, 11 Factory Acceptance Test and Shipboard Trials of Engines*.

9.3 Performance testing

9.3.1 It is to be verified that the propeller performs satisfactorily under ahead and astern conditions. Where controllable pitch propellers are fitted, the free route astern trial is to be carried out with the propeller blades set in the full pitch astern condition.

9.3.2 The reversing characteristics of the propulsion plant, including the blade pitch control system of controllable pitch propellers, are to be demonstrated and recorded during trials.

9.3.3 It is to be verified that large movements of resiliently mounted machinery do not occur during start up and stop, or during normal operating conditions.

9.3.4 The installation should be tested to ensure that gas turbines cannot be continuously operated within any speed range where excessive vibration, stalling or surging may be encountered.

9.3.5 For main propulsion systems with reversing gears, controllable pitch propellers or electric propeller drive, running astern is not to lead to the overload of propulsion machinery.

Contents

■ *Section 1*
General requirements

1.1 Application

1.1.1 The requirements of this Chapter are applicable to reciprocating internal combustion engines operating on liquid, gas or dual fuel (hereinafter referred to as engines) for main propulsion and essential auxiliary services. *Pt 10, Ch 1, 3 Crankshaft design* is not applicable to auxiliary engines having powers of less than 110 kW.

1.1.2 Engines providing power for services essential to the safety of the vessel are to be constructed under survey and in accordance with the requirements of this Chapter (*see also Pt 1, Ch 2, 3.9 Class notations (machinery) 3.9.1*).

1.1.3 This Chapter is to be read in conjunction with the General Requirements for Machinery in *Pt 9 General Requirements for Machinery*.

1.2 Scope

1.2.1 For the purposes of this Chapter engine type, expressed by the manufacturer/licensor's designation, is defined by:

(a) the bore and stroke;
(b) the method of injection (i.e. direct injection, indirect injection, pilot injection);
(c) the fuel pump and injection system (independent line to fuel oil valve, common rail);
(d) the valve and injection operation (by cams or electronically controlled);
(e) the fuel(s) used (liquid, dual-fuel, gaseous, etc);
(f) the working cycle (4-stroke, 2-stroke);
(g) the gas exchange (naturally aspirated, turbocharged, etc.);
(h) the method of turbocharging (pulsating system, constant pressure system);

(i) the charging air cooling system (with or without intercooler, number of stages);
(j) cylinder arrangement (in-line, vee, etc.);
(k) the maximum continuous power per cylinder (or maximum continuous brake mean effective pressure) at maximum continuous speed;
(l) the manufacturer and type of governor (and control system if applicable) fitted.

1.2.2 A complete engine includes the control system, turbocharger(s) and all ancillary systems and equipment referred to in this Chapter that are used for operation of the engine for which there are rule requirements; this includes systems allowing the use of different fuel types.

1.2.3 Arrangements for gas only or dual fuel engines will be specially considered. For the requirements for trunk piston internal combustion engines supplied with low pressure (less than 1 MPa) natural gas (methane) as fuel, *see Rules and Regulations for the Classification of Ships, July 2021 Pt 5, Ch 2, 15 Engines supplied with low pressure gas*.

1.2.4 Primary exhaust gas emissions abatement plant (where fitted) is to meet the requirements of this Chapter; additionally, it is to meet the requirements of *Pt 15, Ch 3, 14 Emissions abatement plant*. Where secondary exhaust gas emissions abatement systems are fitted to engines, they are to meet the requirements of *Pt 15, Ch 3, 14 Emissions abatement plant*s.

1.3 Approval process

1.3.1 All engines intended for installation on a LR Class ship are to be Type Approved by LR(*see* Lloyd's Register Type Approval System Procedure TA14 for details of the LR Type Approval process)

1.3.2 Each complete engine, as defined in *Pt 10, Ch 1, 1.2 Scope*, intended for installation on an LR Classed vessel, is to have an LR Engine Certificate.

1.3.3 For the first engine of a type, the type approval process and the engine certification process may be performed simultaneously.

1.3.4 To apply for an LR Engine Certificate, the following are to be submitted:

(a) a list of all documents identified in the 'for information' and 'for appraisal' columns of *Table 1.1.1 Plans and particulars to be submitted* as part of the engine Type Approval and identify any plans that have been modified.
(b) where there is a licensor/licensee arrangement, the list required by *Pt 10, Ch 1, 1.3 Approval process 1.3.4*(a) is to cross-reference the drawings submitted by the designer as part of the engine Type Approval. This list is to identify all changes where the approved design has been modified by the licensee. Where the licensee proposes design modifications to components, a statement is to be made confirming the licensor's acceptance of the proposed changes. If designer/licensor's acceptance is not confirmed, the engine is to be regarded as a different type and is subject to the complete appraisal and type approval process.
(c) all documents with changes from the approved design are to be submitted for review/appraisal.

In all cases the complete set of endorsed documents and the list referenced in *Pt 10, Ch 1, 1.3 Approval process 1.3.4*(a), which are to be provided by the manufacturer, will be required by the Surveyor(s) attending the manufacturer's works. Where a licensee/licensor arrangement is in place, this set of documents may be a combination of licensor and licensee documents.

1.3.5 An LR Engine Certificate is issued upon satisfactory completion of engine assembly, with associated component testing (*see Pt 10, Ch 1, 2 Materials and components*) and factory acceptance testing (*see Pt 10, Ch 1, 11 Factory Acceptance Test and Shipboard Trials of Engines*) or, issued in accordance with the alternative approach for product assurance approved by LR, *see Pt 9, Ch 2, 1.3 Alternative approach for product assurance*.

1.3.6 For appraisal of emergency generator engines and turbochargers additional submissions are required. *See Pt 10, Ch 1, 1.4 Submission requirements 1.4.4* and *Pt 10, Ch 1, 1.4 Submission requirements 1.4.5* as applicable.

1.4 Submission requirements

1.4.1 The plans and information are to be submitted as required in *Table 1.1.1 Plans and particulars to be submitted* and *Pt 10, Ch 1, 1.4 Submission requirements 1.4.2* to *Pt 10, Ch 1, 1.4 Submission requirements 1.4.8* as applicable.

Table 1.1.1 Plans and particulars to be submitted

Document	For information	For appraisal
	(X indicates reasons for submission)	

Engine particulars (LR Form 2073 with general engine and ancillaries information, Project Guide, Marine Installation Manual) , *see* Note 1	X	
Material specifications of principal components with information on non-destructive material tests and pressure tests		X
Engine cross-section	X	
Engine longitudinal section	X	
Engine frames, welding drawings, *see* Notes 2 and 3		X
Main engine foundation and holding down and securing arrangements	X (metal chocks)	X (non-metallic chocks)
Bedplate and crankcase of cast design	X	
Bedplate and crankcase of welded design, with welding details and welding instructions, *see* Notes 2 and 3		X
Bedplate/oil sump welding drawings, *see* Note 2		X
Thrust bearing assembly, *see* Note 4	X	
Thrust shaft or intermediate shaft (if integral with engine)		X
Thrust bearing bedplate of welded design, with welding details and welding instructions, *see* Note 2		X
Frame (*see* Note 3), framebox (*see* Note 3), and gearcase of cast construction	X	
Tie rod	X	
Connecting rod, assembly, *see* Note 5	X	
Piston rod, assembly, *see* Note 5	X	
Piston, assembly, *see* Note 5	X	
Piston head	X	
Cylinder jacket/block of cast construction, *see* Note 3	X	
Cylinder head, assembly, *see* Note 5	X	
Cylinder liner	X	
Counterweights (if not integral with crankshaft), including fastening	X	
Crankshaft, details (for each crankthrow)		X
Crankshaft, assembly (for each crankthrow)		X
Crankshaft calculations (*see Pt 10, Ch 1, 2 Materials and components*)	X	
Camshaft drive, assembly, *see* Note 5	X	
Flywheel or turning-wheel	X	
Shaft coupling interface arrangement including dimensions and material details		X
Details of shielding and insulation of exhaust pipes and other parts operating at an elevated temperature, which might be impinged by flammable fluid(s) as a result of a system failure	X	
Schematic layout or other equivalent documents for the engine, *see* Note 6:		
• Starting and control air systems.		X

• Fuel system.		X
• Lubricating oil system.		X
• Cooling water system.		X
• Hydraulic systems.		X
• Engine control and safety system.		X
High pressure fuel injection pump assembly	X	
High pressure parts for fuel oil injection system, *see* Note 7		X
Shielding arrangements for high pressure piping - fuel, hydraulic & flammable oils (*see Pt 10, Ch 1, 8.1 Fuel oil and hydraulic and high pressure oil systems 8.1.4*)		X
Fastening arrangements for main bearings	X	
Fastening arrangements for cylinder heads and exhaust valve (two stroke design)	X	
Fastening arrangements for connecting rods	X	
Vibration dampers/de-tuners and moment compensators	X	
Construction and arrangement of vibration dampers	X	
Details of mechanical joints of piping systems		X
Oil mist detection and/or alternative arrangements		X
Construction of accumulators (common rail) for electronically controlled engine		X
Construction of common accumulators (common rail) for electronically controlled engine		X
Construction of accumulators for hydraulic oil and fuel oil		X
Arrangement and details of the crankcase explosion relief valve where applicable (*see Pt 10, Ch 1, 10 Safety arrangements*)		X
Calculation results for crankcase explosion relief valves (*see Pt 10, Ch 1, 10 Safety arrangements*)		X
Construction and arrangements of hydraulic systems for actuation of sub-systems:		
• Control valves, high-pressure pumps, pipes and accumulators.	X	
• Drive for high-pressure pumps.	X	
• Valve bodies, if applicable.	X	
For engine control, alarm monitoring and safety systems, the plans and information required by *Pt 10, Ch 1, 1.4 Submission requirements 1.4.3*, *see* Note 8		X
Generator test results that state the engine maximum load steps which satisfy the quality of power supply requirements specified in *Pt 16, Ch 2, 1.8 Quality of power supplies*		X
Planned operating profiles for the vessel at sea and during manoeuvring as agreed with the Operators		X
List of sub-contractors for main parts	X	

Operation and service manuals, *see* Note 9	X	
Risk-based analysis (for engine control system), *see* Note 10	X	
Test program resulting from risk-based analysis (for engine control system), *see* Note 10	X	
Production specifications for castings and welding procedures	X	
Evidence of quality control system for engine design, production and in-service maintenance, *see* Notes 5 and 11	X	
Type approval certification for environmental tests of control components, *see* Note 12	X	
Details of the engine type test program and the type test report, *see* Note 13		X
Engine test schedule (FAT & shipboard trials, *see Pt 10, Ch 1, 1.4 Submission requirements 1.4.2*)		X
Documentation verifying compliance with inclination limits (*see Pt 9, Ch 1, 4.2 Inclinations of the craft*)		X
Combustion pressure-displacement relationship		X

Plans and details for dead ship condition starting arrangements, *see Pt 10, Ch 1, 9.1 Dead ship condition starting arrangements*	X

Note 1. LR Form 2073 will be supplied on application. Note that the turbochargers, if required to be type approved, are to have plans and particulars submitted as detailed in *Pt 10, Ch 1, 1.4 Submission requirements 1.4.4*

Note 2. For approval of materials and weld procedure specifications. The weld procedure specification is to include details of pre- and post-weld heat treatment, weld consumables and fit-up conditions.

Note 3. For each cylinder for which dimensions and details differ.

Note 4. If integral with engine and not integrated in the bedplate.

Note 5. Including identification of components to ensure traceability in accordance with the *Rules for Materials*.

Note 6. Details of the system so far as supplied by the engine manufacturer such as: main dimensions, operating media and maximum working pressures.

Note 7. The documentation to contain specifications for pressures, pipe dimensions and materials.

Note 8. The submission is to include a general overview of the operating principles, supported by schematics explaining the functionality of individual systems and sub-systems. The information is to relate to the engine capability and functionality under defined operating and emergency conditions such as recovery from a failure or malfunction, with particular reference to the functioning of programmable electronic systems and any sub-systems. The information is also to indicate if the engine has different modes of operation, such as to limit exhaust gas emissions and/or to run under an economic fuel consumption mode or any other mode that is electronically controlled.

Note 9. Operational manuals are to contain maintenance requirements (servicing and repair) including details of any special tools and gauges that are to be used with their fitting/settings together with any test requirements on completion of maintenance. They are to include a description of each system's particulars and include reference to the functioning of sub-systems.

Note 10. Where engines rely on hydraulic, pneumatic or electronic control of fuel injection and/or valves, the risk-based analysis is to address the mechanical, pressure containing, electrical, electronic and programmable electronic systems and arrangements that support the operation of the engine. It is to demonstrate that failure of the control system will not result in the operation of the engine being degraded beyond acceptable performance criteria for the engine and that suitable risk mitigation has been achieved in accordance with *Pt 10, Ch 1, 4.2 Risk-based analysis*.

Note 11. Including quality plan for sourcing, traceability, design, installation and testing of all components used in the fuel and hydraulic oil systems installed with the engine.

Note 12. Tests are to demonstrate the ability of the control, protection and safety equipment to function as intended under the specified testing conditions as per Lloyd's Register Type Approval Test Specification No. 1 *Performance and Environmental Test Specification for the following Environmentally Tested Products used in Marine Applications: Electrical Equipment Control and Monitoring Equipment Instrumentation and Internal Communication Equipment Programmable Electronic Systems*.

Note 13. The type test report may be submitted shortly after the conclusion of the type test. For electronically controlled engines evidence of type testing of the engine with the programmable electronic system, or a proposed factory acceptance test plan at the engine builders with the programmable electronic system functioning, is to be submitted to verify the functionality and behaviour under normal operating and fault conditions of the programmable electronic control system.

1.4.2 A schedule of testing at engine packager's or system integrator's facility, pre-sea trial commissioning and sea trials is to be submitted. The test schedules are to identify all modes of engine operation and the sea trials are to include typical port manoeuvres under the intended engine operating modes. The schedule is to include:

(a) testing and trials to demonstrate that the engine is capable of operating as described in (a)*Pt 10, Ch 1, 1.4 Submission requirements 1.4.1,* Note 10;

(b) tests to verify that the response of the complete mechanical, hydraulic, electrical and electronic system is as predicted for the intended operational modes; and

(c) testing required to verify the conclusions of the risk-based analysis.

The scope of these tests is to be agreed with LR based on the risk-based analysis.

1.4.3 In addition to the applicable plans and particulars required by *Pt 16, Ch 2, 1.2 Documentation required for design review 1.2.3* to *Pt 16, Ch 2, 1.2 Documentation required for design review 1.2.6*, the following information for control, alarm, monitoring and safety systems relating to the operation of an electronically controlled engine is to be submitted:

(a) Engine configuration details, *see Pt 10, Ch 1, 4.3 Control engineering systems 4.3.2*

(i) Local and remote means to carry out system configuration.
(ii) Engine builder procedures for undertaking configuring.
(iii) Roles and responsibilities for configuration (e.g., Engine builder, engine packager, system integrator or other nominated party) with accompanying schedule.
(iv) Configurable settings and parameters (including those not to be modified from a default value).
(v) Configuration for propulsion, auxiliary or emergency engine application.

(b) Software quality plans, including configuration management documents;
(c) Software safety evidence; and
(d) Software conformity assessment report.

Configuration records are to be maintained and are to be made available to the Surveyor at testing and trials and on request in accordance with *Pt 16, Ch 1, 1.4 Alterations and additions* and *Pt 16, Ch 1, 7.1 General 7.1.3*.

1.4.4 Emergency generator engine plans, information and test schedules, required for design appraisal, are to be in accordance with *Pt 16, Ch 1 Control Engineering Systems*.

1.4.5 For turbochargers, the following plans and particulars are to be submitted. The submission requirements vary depending on the category of the turbocharger; categories A, B and C are defined in *Pt 10, Ch 1, 12.1 General 12.1.2*:

(a) Category A (on request):

(i) Turbocharger specification including type, compression ratio and operating condition
(ii) Cross sectional drawing with principal dimensions and names of components.
(iii) Containment test report.
(iv) Test program.

(b) Category B:

(i) Turbocharger specification including type of turbine and compressor, compression ratio, bearing and cooling method
(ii) Cross-sectional drawing with principal dimensions and materials of housing components for containment evaluation.
(iii) Documentation of containment in the event of disc fracture
(iv) Operational data and limitations, i.e.:

- Maximum permissible operating speed (rpm)
- Alarm level for over-speed
- Maximum permissible exhaust gas temperature before turbine
- Alarm level for exhaust gas temperature before turbine
- Minimum lubrication oil inlet pressure
- Lubrication oil inlet pressure low alarm set point
- Maximum lubrication oil outlet temperature
- Lubrication oil outlet temperature high alarm set point
- Maximum permissible vibration levels, i.e. self- and externally generated vibration (Alarm levels may be equal to permissible limits but are not to be reached when operating the engine at 110 per cent power or at any approved intermittent overload beyond 110 per cent.)

(v) Arrangement of lubrication system, all variants within a range.
(vi) A list of main current suppliers and subcontractors for rotating parts and an operation and maintenance manual.
(vii) Type test reports

(c) Category C:

(i) Plans and particulars as for Category B.
(ii) Drawings of the housing and rotating parts (Shaft, wheels, blades and nozzle) including details of blade fixing for turbine and compressor.
(iii) Material specifications (including density, Poisson's ratio, range of chemical composition and mechanical properties (at room temperature), and high-temperature strength characteristics as well as creep rate and rupture strength for the design service life (parts subject to 450 degrees Celsius or more)) of all parts mentioned above including details of the material and quality control system to be used for these parts.
(iv) Welding details and welding procedure of above mentioned parts, if applicable.
(v) Documentation* of safe torque transmission when the disc is connected to the shaft by an interference fit
(vi) Information on expected lifespan, considering creep, low cycle fatigue and high cycle fatigue.

(vii) Operation and maintenance manuals*.

(viii) Arrangements of cooling system

Note *. Documentation is to be provided applicable to two representative sizes in a generic range of turbochargers.

1.4.6 The following information is to be submitted to LR for acceptance of oil mist detection equipment and alarm arrangements:

(a) Description of oil mist detection equipment and system including alarms.

(b) Copy of the test house report in accordance with the requirements of Test Specification No. 4 – Type Testing of Reciprocating Internal Combustion Engines and Associated Ancillary Equipment *See also Pt 10, Ch 1, 14.4 Crankcase oil mist detection system 14.4.4*.

(c) Schematic layout of engine oil mist detection arrangements showing location of detectors/sensors and piping arrangements and dimensions.

(d) Maintenance and test manual which is to include the following information:

(i) Intended use of equipment and its operation;

(ii) Functionality tests to demonstrate that the equipment is operational and that any faults can be identified and corrective actions notified;

(iii) Maintenance routines and spare parts recommendations;

(iv) Limit setting and instructions for safe limit levels; and

(v) Where necessary, details of configurations in which the equipment is and is not to be used.

1.4.7 Where engine components are subject to autofrettage the following information is to be submitted (*see also Pt 10, Ch 1, 2.4 Autofrettage*):

(a) Drawings and other related documents/information for products to be subjected to autofrettage, including material grade and dimensions.

(b) Details of product quality assurance processes.

(c) Place of manufacture and details of external providers of products subjected to autofrettage.

(d) A report detailing how repeatability and reliability of autofrettage process are achieved. This is to include the following:

(i) Method of autofrettage.

(ii) Method to control extent of autofrettage.

(iii) Calibration of the autofrettage system.

(iv) Details of how the critical parameters affecting product characteristics are controlled.

(e) Method for recording results and list of data that is recorded.

(f) Finished component and/or system testing.

1.4.8 Where considered necessary Lloyd's Register (hereinafter referred to as 'LR') may require additional documentation to be submitted.

1.5 Additional submission requirements

1.5.1 In addition to the requirements of *Pt 10, Ch 1, 1.4 Submission requirements* and *Table 1.1.1 Plans and particulars to be submitted*, the plans and information in *Pt 10, Ch 1, 1.5 Additional submission requirements 1.5.2* to *Pt 10, Ch 1, 1.5 Additional submission requirements 1.5.3* and *Table 1.1.2 Plans and particulars to be submitted* are to be submitted for engines installed on special service craft.

Table 1.1.2 Plans and particulars to be submitted

Document	For information	For appraisal
	(*X indicates reason for submission)*	
Calculations and information for short term high power operation where applicable.	X	
Arrangement of interior lighting, where provided.	X	

Engine Type test programme, where required including proposals for short term high power operation	X	
Details of any fuel treatments, fuel additives or fuel emulsification used as a primary means of reducing exhaust gas emissions, together with information confirming that such treatments are suitable for use with the engine.		X
Exhaust gas emissions abatement equipment fitted within the exhaust arrangement or as part of the engine (where applicable).		X
Exhaust gas system back pressure along with engine allowable exhaust back pressure curve(s) where emissions abatement equipment is installed as part of the exhaust system.	X	

1.5.2 Where it is proposed to use alloy castings, micro alloyed or alloy steel forgings or iron castings, details of the chemical composition, heat treatment and mechanical properties are to be submitted.

1.5.3 A Risk Assessment (RA) as detailed in *Pt 9 General Requirements for Machinery* is to be submitted. The RA is to include the following associated sub-systems:

- Starting and stopping.
- Fuel oil.
- Lubricating oil.
- Cooling water (fresh and sea).
- Air induction.
- Exhaust.
- Engine mounting.
- Control and monitoring.
- Electrical power supplies.
- Hydraulic oil (for valve lift).

1.5.4 Plans and details for dead craft condition starting arrangements are to be submitted for appraisal, *see Pt 10, Ch 1, 9.1 Dead ship condition starting arrangements*.

■ *Section 2*
Materials and components

2.1 Crankshaft materials

2.1.1 The specified minimum tensile strength of castings and forgings for crankshafts is to be selected within the following general limits:

(a) Carbon-manganese steel castings -

400 to 550 N/mm^2.

(b) Carbon-manganese steel forgings (normalised and tempered) -

400 to 600 N/mm^2.

(c) Carbon-manganese steel forgings (quenched and tempered) -

not exceeding 700 N/mm^2.

(d) Alloy steel castings -

not exceeding 700 N/mm^2.

(e) Alloy steel forgings -

not exceeding 1000 N/mm^2.

(f) Spheroidal or nodular graphite iron castings -

370 to 800 N/mm^2.

2.2 Testing and inspection

2.2.1 Materials and components for engines are to be manufactured, tested and documented in accordance with *Table 1.2.1 Summary of testing and associated documentation for engine components* under a quality control system that is suitable for the actual engine types to be certified by LR. *See also Pt 10, Ch 1, 2.2 Testing and inspection 2.2.8* and the applicable requirements specified in the *Rules for the Manufacture, Testing and Certification of Materials, July 2021*.

2.2.2 Where an LR quality scheme is in place (*see Pt 9, Ch 2, 1.3 Alternative approach for product assurance*), the testing and documentation requirements in *Table 1.2.1 Summary of testing and associated documentation for engine components* will be in accordance with a specific LR quality scheme certification schedule identifying the tests, intervention requirements and associated documentation including types of certificates that are to be issued.

2.2.3 The testing and inspection in *Table 1.2.1 Summary of testing and associated documentation for engine components* is to be documented by the manufacturer (e.g. manufacturer certified materials testing or manufacturer issued NDT report as applicable), except where LR intervention is explicitly required, in which case an LR Component Certificate is to be issued which confirms conformity with the Rule requirements, with tests carried out on either the finished component itself or on samples taken from earlier stages in the production of the component, as applicable.

2.2.4 The manufacturer is not exempted from responsibility for any relevant tests and inspections of those parts for which documentation is not explicitly requested by LR Manufacturers are to be equipped in such a way that all materials and components can be consistently produced to the required standard. This includes production and assembly lines, machining units, special tools and devices, assembly and testing rigs as well as all lifting and transportation devices.

2.2.5 Where *Table 1.2.1 Summary of testing and associated documentation for engine components* states that a test report is required, this is to be issued by the manufacturer and provided for review by the Surveyor. The report is to identify the samples from the current production batch that have been tested and inspected to confirm that the component complies with all applicable requirements.

2.2.6 Where a manufacturer's document (test certificate or NDT report) is required in *Table 1.2.1 Summary of testing and associated documentation for engine components*, this is to be issued by the manufacturer and provided for review by the Surveyor. The document is to comply with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials, July 2021*, *Ch 1, 3.1 General 3.1.3.(c)* or *Ch 1, 5.6 Non-destructive examination reports 5.6.1* as applicable and is to identify the tests and inspections that have been carried out on the finished component itself or, where applicable, on samples taken from earlier stages in the production of the component.

2.2.7 Components and materials not specified in *Table 1.2.1 Summary of testing and associated documentation for engine components* or of novel design will be specially considered upon submission of their details.

2.2.8 Where an LR material certificate is specified for components listed in *Table 1.2.1 Summary of testing and associated documentation for engine components*, the material is to be from an LR approved manufacturer, and manufactured within the scope of approval of that manufacturer, except where explicitly stated otherwise in other Parts and Chapters of the Rules.

Table 1.2.1 Summary of testing and associated documentation for engine components

Part	Material properties *see* Note 2	Non-destructive examination	Hydraulic testing *see* Note 4	Dimensional inspection *see* Note 3	Visual inspection	Applicable to engines	Final document to be issued
Welded bedplate	W (C + M)	W (UT + CD)	-	-	LR(V) fit-up + post-welding	All	LR Component Certificate
Bearing transverse girders (cast steel)	W (C + M)	W (UT + CD)	-	-	LR(V)	All	LR Component Certificate
Welded frame box *see* Note 5	W (C + M)	W (UT + CD)	-	-	LR(V) fit-up + post-welding	All	LR Component Certificate
Cylinder block (grey cast iron or spheroidal graphite cast iron)	-	-	W (P) *see* Note 6	-	-	>400kW-cylinder	W Hydraulic Test Certificate
Welded cylinder frames *see* Note 5	W (C + M)	W (UT + CD)	-	-	LR(V) fit-up + post-welding	Crosshead	LR Component Certificate
Engine block (grey cast iron)	-	-	W (P) *see* Note 6	-	-	>400kW/ cylinder	W Hydraulic Test Certificate
Engine block (spheroidal graphite cast iron)	W (M)	-	W (P) *see* Note 6	-	-	>400kW/ cylinder	W Material Properties Certificate W Hydraulic Test Certificate
Cylinder liner	W (C + M)	-	W (P) *see* Note 6	-	-	B>300mm	W Material Properties Certificate W Hydraulic Test Certificate
Cylinder head (grey cast iron or spheroidal graphite cast iron)	-	-	W (P)	-	-	B>300mm	W Hydraulic Test Certificate
Cylinder head (cast steel)	W (C + M)	W (UT + CD)	W (P)	-	LR(V)	B>300mm	LR Component Certificate
Cylinder head (forged)	W (C + M)	W (UT + CD)	W (P)	-	LR(V)	B>300mm	LR Component Certificate
Piston crown (cast steel)	W (C + M)	W (UT + CD)	-	-	LR(V)	B>400mm	LR Component Certificate

Piston crown (forged)	W (C + M)	W (UT + CD)	-	-	LR(V)	B>400mm	LR Component Certificate
Crankshaft (one piece)	LR(C + M)	W (UT + CD)	-	W	LR(V) (Random, of fillets and oil bores)	All	LR Component Certificate
Semi-built crankshaft (crankthrow, forged main journal and journals with flange)	LR(C + M)	W (UT + CD)	-	W	LR(V) (Random, of fillets and shrink fittings)	All	LR Component Certificate
Exhaust gas valve cage	-	-	W (P)	-	-	Crosshead	W Hydraulic Test Certificate
Piston rod	LR(C + M)	W (UT + CD)	-	-	LR(V) (Random)	Crosshead B>400mm	LR Component Certificate
Crosshead pin	LR(C + M)	W (UT + CD)	-	-	LR(V) (Random)	Crosshead	LR Component Certificate
Connecting rod with cap	LR(C + M)	W (UT + CD)	-	W	LR(V) (Random, of all surfaces in particular those shot peened)	All	LR Component Certificate
Crankshaft coupling bolts	LR(C + M)	UW (UT + CD)	-	W	LR(V) (Random, of interference fit)	All	LR Component Certificate
Bolts and studs for cylinder heads, crossheads, main bearings and connecting rods *see* Note 8	W (C + M)	W (UT + CD)	-	TR [thread making for connecting rods]	-	B>300mm	W Material Properties Certificate W Non-Destructive Examination Report W Test Report
Tie rod *see* Note 9	W (C + M)	W (UT + CD)	-	TR [thread making]	LR(V) (Random)	Crosshead	LR Component Certificate
High pressure fuel injection system – pump body (pressure side) *see* Notes 10 and 11	W(C + M)	-	W (Lesser of P or *p* +30 MPa)	-	-	B>300mm	W Material Properties Certificate W Hydraulic Test Certificate or Test Report. *See* Note 14
			TR (Lesser of P or *p* +30 MPa)			B≤300mm	

High pressure fuel injection system – valves *see* Note 10	-	-	W (Lesser of P or *p* +30 MPa	-	-	B>300mm	W Hydraulic Test Certificate or Test Report. *See* Note 14
			TR (Lesser of P or *p* +30 MPa)			B>300mm	
High pressure fuel injection pipes including common rail *see* Note 10	W (C + M)	-	LR (Lesser of P or *p* +30 MPa)	-	-	B>300mm	W Material Properties Certificate W Hydraulic Test Certificate or Test Report. *See* Note 14
			TR (Lesser of P or *p* +30 MPa			B≤300mm	
High pressure common servo oil system	W (C + M)	-	W (Lesser of P or p +30 MPa)	-	-	B>300mm	W Material Properties Certificate W Hydraulic Test Certificate or Test Report. *See* Note 14
			TR (Lesser of P or p +30 MPa)			B≤300mm	
Coolers, both sides *see* Note 12	W (C + M)	-	W (P)	-	-	B>300mm	W Material Properties Certificate W Hydraulic Test Certificate. *See* Note 14
Accumulator	W (C + M)	-	W (Lesser of P or *p* +30 MPa)	-	-	Accumulators with a capacity >0,5l	W Material Properties Certificate W Hydraulic Test Certificate. *See* Note 14
Piping, pumps, actuators, etc., for hydraulic drive of valves, if applicable	W (C + M)	-	W (P)	-	-	>800kW/ cylinder	W Material Properties Certificate W Hydraulic Test Certificate. *See* Note 14

Engine-driven pumps (oil, water, fuel, bilge) excluding those listed separately above	-	-	W (P)	-	-	>800kW/ cylinder	W Hydraulic Test Certificate. *See* Note 14
Bearings (main, crosshead, and crankpin) *see* Note 13	TR [C]	TR [UT]	-	W	-	>800kW/ cylinder	TR Material Properties TR Non-Destructive Examination Report W Inspection Certificate

SYMBOLS:

B = Bore dimension, refers to engine cylinder bores	*p* = Maximum working pressure of item concerned
C = Chemical composition analysis	P = Pressure test at 1,5*p*
M = Mechanical property analysis	V = Visual examination of accessible surfaces
UT = Ultrasonic testing (*see* Note 1)	- = No explicit requirement for documentation or testing
CD = Crack detection by MPI or DPT (*see* Note 7)	LR ( ) = Test/inspection to be certified by LR
W ( ) = Test/inspection to be certified by manufacturer	TR[ ] = Test report required for process in brackets (*see Pt 10, Ch 1, 2.2 Testing and inspection 2.2.6*)

Note 1. Ultrasonic testing is not required for components manufactured from cast iron.

Note 2. Material properties include chemical composition and mechanical properties, as identified in the table above. Where mechanical testing is required this is to include testing of surface treatment, such as surface hardening (hardness, depth and extent), peening and rolling (extent and applied force) as applicable. Mechanical tests are to be conducted after the final heat treatment has been applied.

Note 3. Dimensional inspection, including assessment of surface condition.

Note 4. Hydraulic testing is applied on the water/oil side of the component. The full lengths of cooling spaces are to be tested, where applicable. Where design or testing features may require modification of these test requirements, special consideration may be given.

Note 5. Where welding is carried out, welding and welder qualifications are to be carried out in accordance with the *Rules for the Manufacture, Testing and Certification of Materials, July 2021*, *Ch 12 Welding Qualifications*.

Note 6. Hydraulic testing is also required for those parts filled with cooling water and having the function of containing the water which is in contact with the cylinder or cylinder liner.

Note 7. Magnetic particle testing is to be carried out on ferromagnetic materials, penetrant testing is only to be carried out on non-ferritic materials. Visual examination alone is considered insufficient. Magnetic particle and dye penetrant testing are to be carried out when the forgings are in the finished machined condition.

Note 8. *See also Rules for the Manufacture, Testing and Certification of Materials, July 2021*, *Ch 5, 3.5 Non-destructive examination 3.5.1* for detailed non-destructive examination requirements for other bolts and studs.

Note 9. Magnetic particle testing of tie rods may be confined to the threaded portions and the adjacent material over a length equal to that of the thread.

Note 10. Where components are subjected to an autofrettage process accepted by LR (*see Pt 10, Ch 1, 2.4 Autofrettage*), the component pressure test may be omitted. The assembled system containing such components is to be shown, where practicable, to be pressure-tight as required for hydraulic systems.

Note 11. Pumps used in jerk or timed pump systems only need to have the assembled high pressure containing components hydraulically tested.

Note 12. Material and component certification for accumulators or coolers which are classed as pressure vessels are dependent on the operating pressure and temperature, *see Pt 15, Ch 4, 1.4 Classification of fusion welded pressure vessels* and *Pt 15, Ch 4, 1.3 Materials*. Charge air coolers are only to be tested on the water side.

Note 13. Ultrasonic testing is required to prove full adhesion between base material and bearing metal.

Note 14. Material certification requirements for pumps and piping components are dependent on the operating pressure and temperature. Requirements given in this Table apply except where alternative requirements are explicitly given elsewhere in the Rules. *See Pt 15, Ch 1, 11.1 Metallic materials*.

2.3 Alignment gauges

2.3.1 All main and auxiliary oil engines exceeding 220 kW (300 shp) are to be provided with an alignment gauge which may be either a bridge weardown gauge, or a micro-meter clock gauge for use between the crankwebs. Only one micrometer clock gauge need be supplied for each ship provided the gauge is suitable for use on all engines.

2.4 Autofrettage

2.4.1 Manufacturers and external providers of products or services, who carry out autofrettage of engine components, are to be apply an approach for product assurance that is accepted by LR.

2.4.2 Documentation for the autofrettage process and the associated approach for product assurance is to be submitted in accordance with *Pt 10, Ch 1, 1.3 Approval process 1.3.6*.

2.4.3 Testing carried out as part of the approach for product assurance is to confirm that the autofrettage process has not detrimentally affected the components and demonstrate that the prescriptive Rule requirements for pressure containment have been met, *see Table 1.2.1 Summary of testing and associated documentation for engine components*.

■ *Section 3*
Crankshaft design

3.1 Application

3.1.1 *Pt 10, Ch 1, 3 Crankshaft design* is not applicable to auxiliary engines having powers of less than 110 kW.

3.2 Scope

3.2.1 The formulae given in this Section are applicable to solid or semi-built crankshafts of forged or cast steel, having a main support bearing adjacent to each crankpin.

3.2.2 This section uses the statically determinate method; alternative methods, including a fully documented stress analysis, will be considered.

3.2.3 Calculations are to be carried out for the maximum continuous power rating for all designed operating conditions.

3.2.4 Designs of crankshafts not included in this scope will be subject to special consideration.

3.2.5 Where a crankshaft design involves the use of surface treated fillets, or when fatigue parameter influences are tested, or when working stresses are measured, the relevant documents with calculations/analysis are to be submitted to LR.

3.2.6 The design of crankshafts is based on an evaluation of safety against fatigue in the highly stressed areas. The calculation is also based on the assumption that the areas exposed to highest stresses are :

(a) fillet transitions between the crankpin and web as well as between the journal and web; and
(b) outlets of crankpin oil bores.

3.2.7 When the journal diameter is equal to or larger than the crankpin diameter, the outlets of main journal oil bores are to be formed in a similar way to the crankpin oil bores, otherwise separate documentation of fatigue safety will be specially considered.

3.2.8 Calculation of crankshaft strength consists initially in determining the nominal alternating bending (*see Pt 10, Ch 1, 3.6 Calculation of bending stresses*) and nominal alternating torsional stresses (*see Pt 10, Ch 1, 3.7 Calculation of torsional stresses*) which when multiplied by the appropriate stress concentration factors (SCF) (*see Pt 10, Ch 1, 3.8 Stress concentration factors*), result in an equivalent alternating stress (uniaxial stress) (*see Pt 10, Ch 1, 3.10 Equivalent alternating stress*). This equivalent alternating stress is then compared with the fatigue strength of the selected crankshaft material (*see Pt 10, Ch 1, 3.11 Fatigue strength*). This comparison will show whether or not the crankshaft concerned is dimensioned adequately (*see Pt 10, Ch 1, 3.12 Acceptability criteria*).

3.2.9 Further information and guidance on crankshaft design is provided in the LR's *Guidance Notes for the Calculation of Stress Concentration Factors, Fatigue Enhancement Methods and Evaluation of Fatigue Tests for Crankshafts.*

3.3 Information to be submitted

3.3.1 For the calculation of crankshafts, the documents and particulars listed below are required. This information is provided by completing LR Form 2073 and submitting the applicable plans required in *Table 1.1.1 Plans and particulars to be submitted*:

- crankshaft drawing (which must contain all data in respect of the geometrical configurations of the crankshaft);
- type designation and kind of engine (in-line engine or V-type engine with adjacent connecting rods, forked connecting rod or articulated-type connecting rod);
- operating and combustion method (2-stroke or 4-stroke cycle/direct injection, precombustion chamber, etc.);
- number of cylinders;
- output power at maximum continuous rating (MCR), in kW;
- output speed at maximum continuous power, in rpm;
- maximum firing pressure, P_{max}, in MPa;
- mean indicated pressure, in MPa;
- charge air pressure (before inlet valves or scavenge ports, whichever applies), in MPa;
- digitised gas pressure/crank angle cycle for MCR (presented at equidistant intervals at least every 5° CA);
- mean piston speed;
- compression ratio;
- vee angle α_v, in degrees;
- firing order numbered from driving end, *see Figure 1.3.1 Designation of cylinders*;
- direction of rotation;
- cylinder diameter, in mm;
- piston stroke, in mm;
- centre of gravity of connecting rod from large end centre, in mm;
- radius of gyration of connecting rod, in mm;
- length of connecting rod between bearing centres, L_H, in mm;
- mass of single crankweb (indicate if webs either side of pin are of different mass values), in kg;
- centre of gravity of crankweb mass from shaft axis, in mm;
- mass of counterweights fitted (for complete crankshaft) indicate positions fitted, in kg;
- centre of gravity of counterweights (for complete crankshaft) measured from shaft axis, in mm;
- all individual reciprocating masses acting on one crank, in kg;
- crankshaft material specification(s) (according to ISO, EN, DIN, AISI, etc.);
- mechanical properties of material (minimum values obtained from longitudinal test specimens):
  - tensile strength, in N/mm^2
  - yield strength, in N/mm^2
  - reduction in area at break, percentage
  - elongation, percentage
- method of manufacture (free form forged, continuous grain flow forged, drop-forged, etc.; with description of the forging process);

- for semi-built crankshafts – minimum and maximum diametral interference, in mm;
- particulars of alternating torsional stress calculations, *see Pt 10, Ch 1, 3.7 Calculation of torsional stresses*.

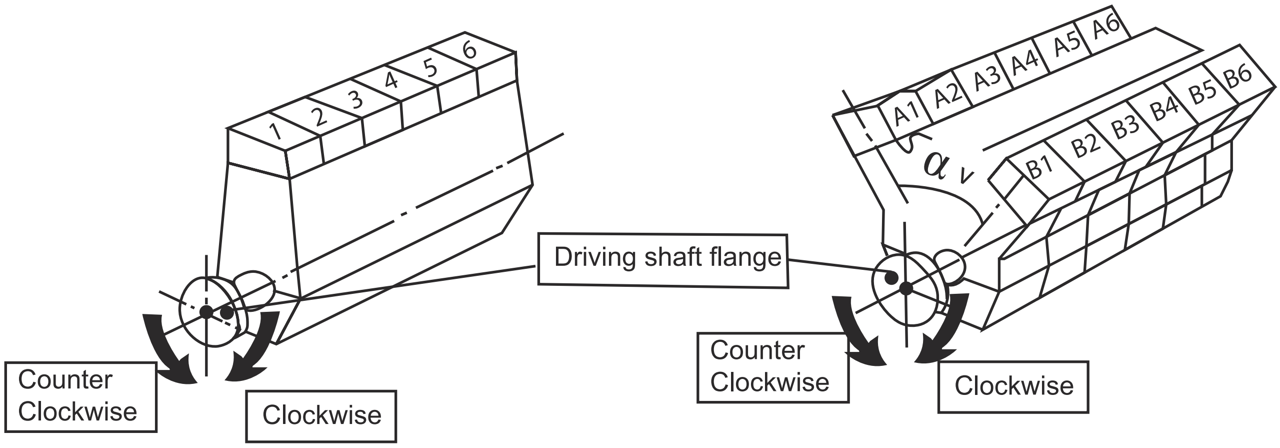


Figure 1.3.1 Designation of cylinders

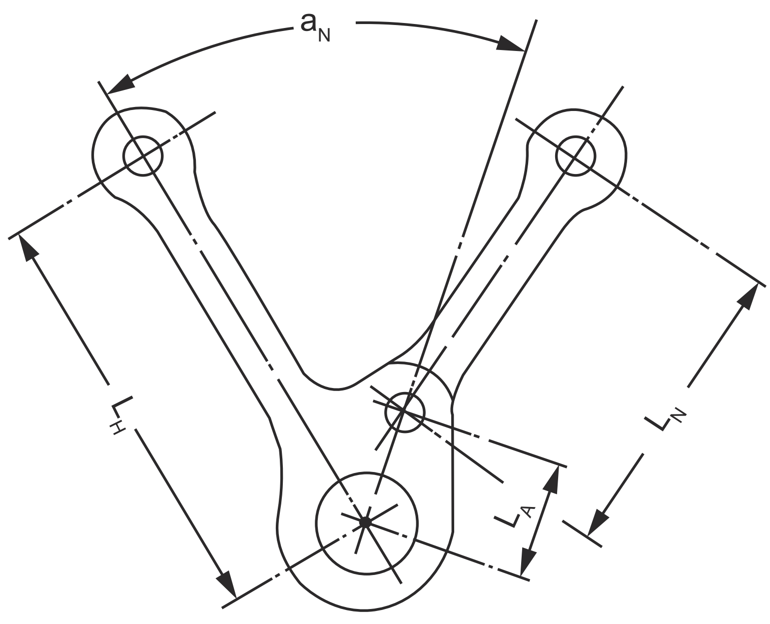


Figure 1.3.2 Articulated-type connecting rod

3.3.2 The following information is also required for appraisal of the crankshaft (not contained in Form 2073):

- for engines with articulated-type connecting rod (*see Figure 1.3.2 Articulated-type connecting rod*);
  - distance to link point L_A, in mm
  - link angle α_N, in degrees
  - connecting rod length L_N, in mm
- firing interval (if applicable) i.e. if not evenly distributed;
- mass of connecting rod (including bearings), in kg;

- mass of piston (including piston rod and crosshead where applicable), in kg;
- every surface treatment affecting fillets or oil holes shall be specified so as to enable calculation according to Chapter 3 of the LR Guidance Notes *for the Calculation of Stress Concentration Factors, Fatigue Enhancement Methods and Evaluation of Fatigue Tests for Crankshafts;*
  - this is to include crankshaft fatigue enhancement factors K_1 and K_2 where applicable.
- maximum alternating torsional stress τ_a (N/mm^2)
- mechanical properties of material (minimum values obtained from longitudinal test specimens), in addition to the information listed above:

  Impact energy K_V, in Joules.

3.4 Symbols

3.4.1 For the purposes of this Chapter the following symbols apply, *see also*

- *Figure 1.3.3 Crank dimensions for overlapped crankshaft*
- *Figure 1.3.4 Crank dimensions for crankshaft without overlap*
- *Figure 1.3.5 Crankpin section through the oil bore*, and
- *Figure 1.3.6 Crankthrow of semi-built crankshaft*

B = transverse breadth of web, in mm

D = crankpin diameter, in mm

D_A = the outside diameter of web or twice the minimum distance between centreline of journals and outer contour of web, whichever is less, in mm

D_{BH} = diameter of axial bore in crankpin, in mm

D_{BG} = diameter of axial bore in journal, in mm

D_G = journal diameter, in mm

D_o = diameter of radial oil bore in crankpin, in mm

D_s = shrink diameter of main journal in web, in mm

E = pin eccentricity

E_m = Young's modulus of crankshaft material, in N/mm^2

F = area related to cross-section of web, in mm^2

K_e = bending stress factor (considers the influence of adjacent crank and bearing restraint)

K = fatigue enhancement factor ($K = K_1.K_2$)

K_1 = fatigue enhancement factor due to manufacturing process

K_2 = fatigue enhancement factor due to surface treatment

L_s = length of shrink fit, in mm

M_{BON} = alternating bending moment calculated at the outlet of crankpin oil bore

M_{BRFN} = alternating bending moment related to the centre of the web, in Nm

M_{TN} = maximum alternating torque, in Nm

M_{Tmax} = maximum value of the torque, in Nm

M_{Tmin} = minimum value of the torque, in Nm

Q_{RFN} = alternating radial force related to the web, in N

R_H, R_G = fillet radius at junction of web and pin or journal, in mm

S = pin overlap, in mm $S = \frac{D + D_G}{2} - E$

T_H, T_G = recess of pin or journal fillet radius into web measured from web face, in mm

W = axial thickness of web, in mm

W_{eqw} = section modulus related to cross-section of web, in mm^3

W_e = section modulus related to cross-section of axially bored crankpin, in mm^3

W_p = polar section modulus related to cross-section of axially bored crankpin or bored journal, in mm^3

y = distance between the adjacent generating lines of journal and pin, in mm

Note For $y \geq 0{,}05D_S$. Where y is less than $0{,}1D_S$, special consideration is to be given to the effect of the stress due to the shrink fit on the fatigue strength at the crankpin fillet.

α_B = bending stress concentration factor for crankpin fillet

α_T = torsional stress concentration factor for crankpin fillet

β_B = bending stress concentration factor for main journal fillet

Note α_B and β_B are defined as the ratio of the maximum equivalent stress (von Mises) occurring in the fillets under bending load, to the nominal bending stress related to the web cross-section. *See Figure 1.3.7 Stress concentration factors in crankshaft fillets*.

β_Q = compression stress concentration factor for main journal fillet

Note β_Q is defined as the ratio of the maximum equivalent stress (von Mises) occurring in the fillet due to the radial force, to the nominal compressive stress related to the web cross-section.

β_T = torsional stress concentration factor for main journal fillet

Note Note. α_T and β_T are defined as the ratio of the maximum equivalent shear stress occurring in the fillets under torsional load, to the nominal torsional stress related to the axially bored crankpin or journal cross-section. *See Figure 1.3.7 Stress concentration factors in crankshaft fillets*.

γ_B = bending stress concentration factor for outlet of crankpin oil bore

γ_T = torsional stress concentration factor for outlet of crankpin oil bore

Note γ_B and γ_T are defined as the ratio of the maximum principal stress occurring at the outlet of the crankpin oil-hole under bending and torsional loads respectively, to the corresponding nominal stress related to the axially bored crankpin cross section. *See Figure 1.3.8 Stress concentration factors and stress distribution at the edges of oil drillings*.

σ_{add} = additional bending stress due to misalignment and bedplate deformation as well as due to axial and bending vibrations, in N/mm^2

σ_B = specified minimum UTS of crankshaft material, in N/mm^2

σ_{BFN} = nominal alternating bending stress related to the web, in N/mm^2

σ_{BG} = alternating bending stress in journal fillet, in N/mm^2

σ_{BH} = alternating bending stress in crankpin fillet, in N/mm^2

σ_{BO} = alternating bending stress in the outlet of the oil bore, in N/mm^2

σ_{BON} = nominal alternating bending stress in the outlet of the oil bore related to the crankpin diameter, in N/mm^2

σ_{QFN} = nominal alternating compressive stress due to radial force related to the web, in N/mm^2

σ_{DW} = allowable fatigue strength of crankshaft, in N/mm^2

σ_{SP} = minimum yield strength of material for journal pin, in N/mm^2

σ_{SW} = minimum yield strength of material for crankweb, in N/mm^2

σ_{TO} = alternating torsional stress in the outlet of the crankpin oil bore, in N/mm^2

σ_y = equivalent alternating stress for crankpin fillet, journal fillet or outlet of crankpin oil bore as applicable, in N/mm^2

τ_H = alternating torsional stress in crankpin fillet, in N/mm^2

τ_G = alternating torsional stress in journal fillet, in N/mm^2

τ_N = calculated nominal alternating torsional stress referred to crankpin or journal (as applicable), in N/mm^2

τ_a = manufacturer stated crankshaft half range torsional stress limit, in N/mm^2

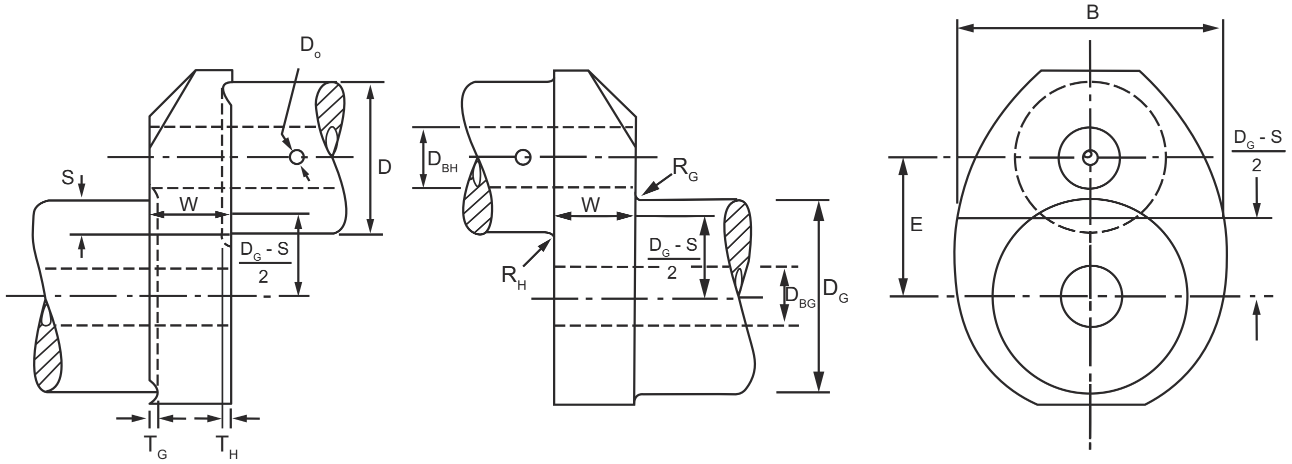
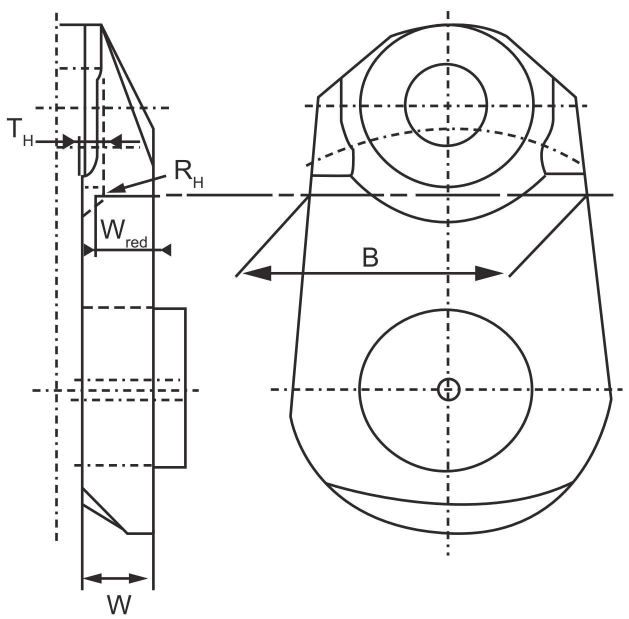


Figure 1.3.3 Crank dimensions for overlapped crankshaft



Crankshaft without overlap

Figure 1.3.4 Crank dimensions for crankshaft without overlap

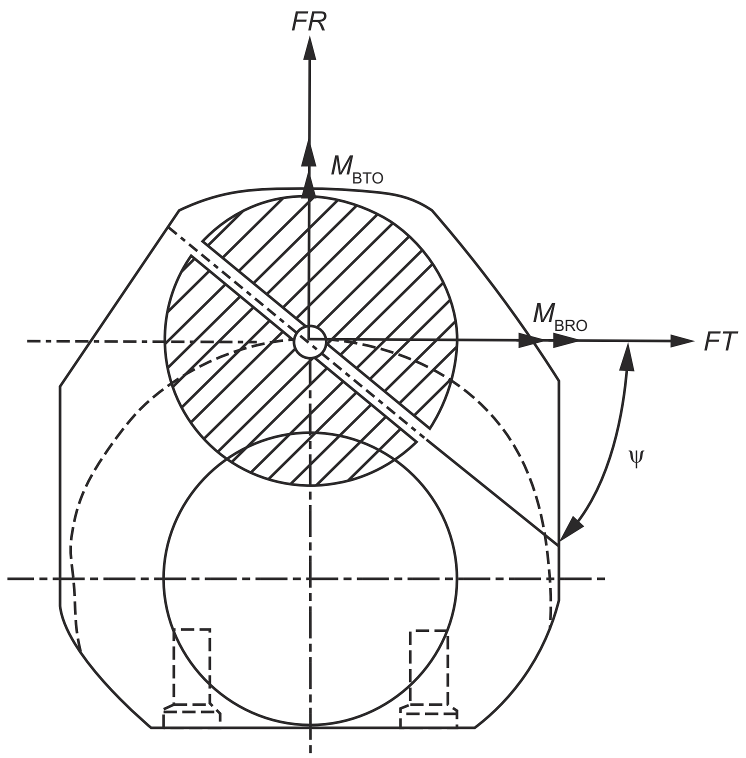


Figure 1.3.5 Crankpin section through the oil bore

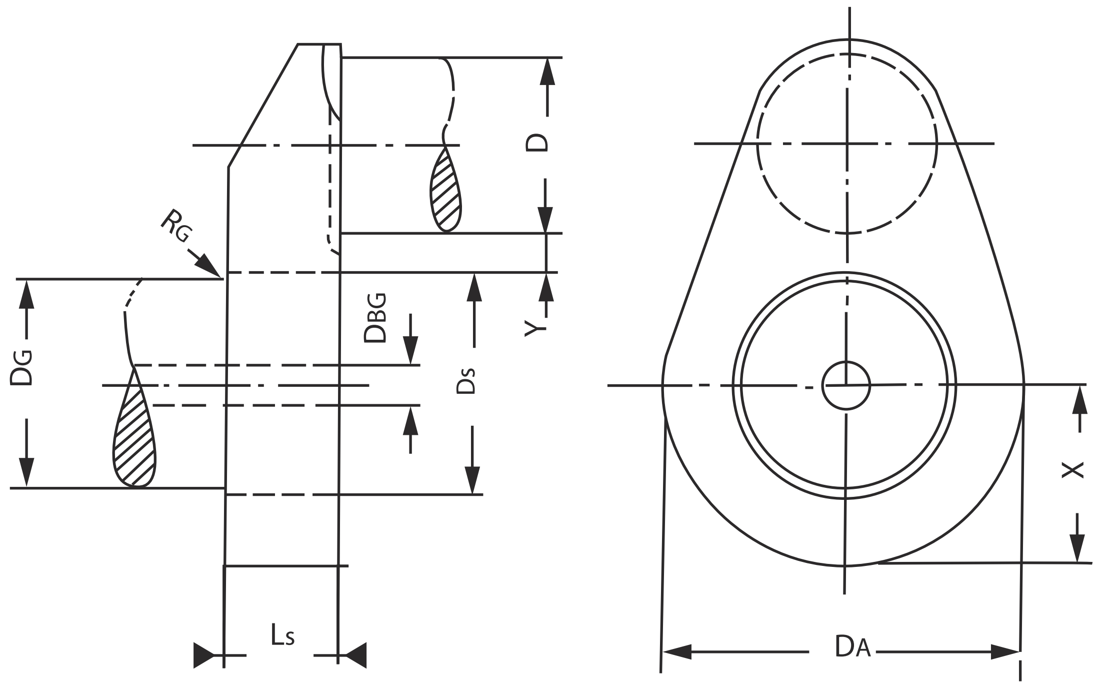
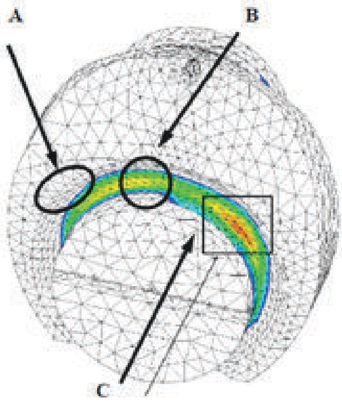


Figure 1.3.6 Crankthrow of semi-built crankshaft



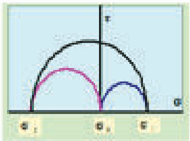
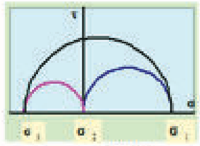
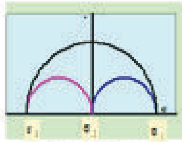
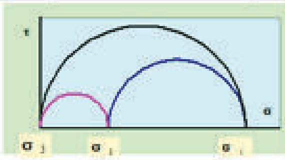
Stress Type	Stress	Max $\|\|\sigma_3\|\|$	Max σ_1	
Torsional loading	Location of maximal stresses	*A*	*C*	*B*
	Typical principal stress system Mohr's circle diagram with $\sigma_2 = 0$	 $\|\|\sigma_3\|\| > \sigma_1$	 $\sigma_1 > \|\|\sigma_3\|\|$	 $\sigma_1 \approx \|\|\sigma_3\|\|$
	Equivalent stress and **S.C.F**	$\tau_{equiv} = \frac{\sigma_1 - \sigma_3}{2}$ S.C.F. $= \frac{\tau_{equiv}}{\tau_n}$ for α_T, β_T		
Bending loading	Location of maximal stresses	*B*	*B*	*B*
	Typical principal stress system Mohr's circle diagram with $\sigma_3 = 0$			$\sigma_2 \neq 0$
	Equivalent stress and **S.C.F**	$\sigma\,\text{equiv} = \sqrt{\sigma_1^2 + \sigma_2^2 - \sigma_1 . \sigma_2}$ S.C.F. $= \frac{\sigma\,\text{equiv}}{\sigma_n}$ for $\alpha_B, \beta_B, \beta_Q$		

Figure 1.3.7 Stress concentration factors in crankshaft fillets

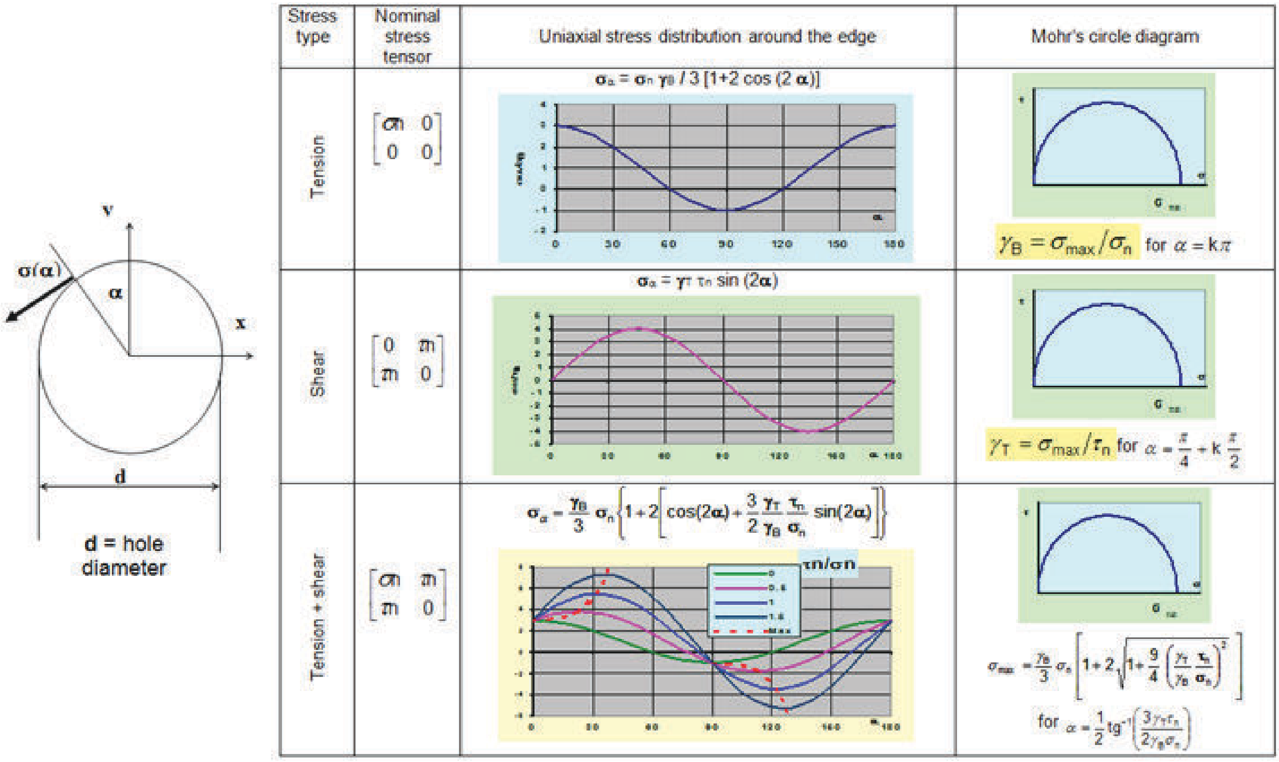
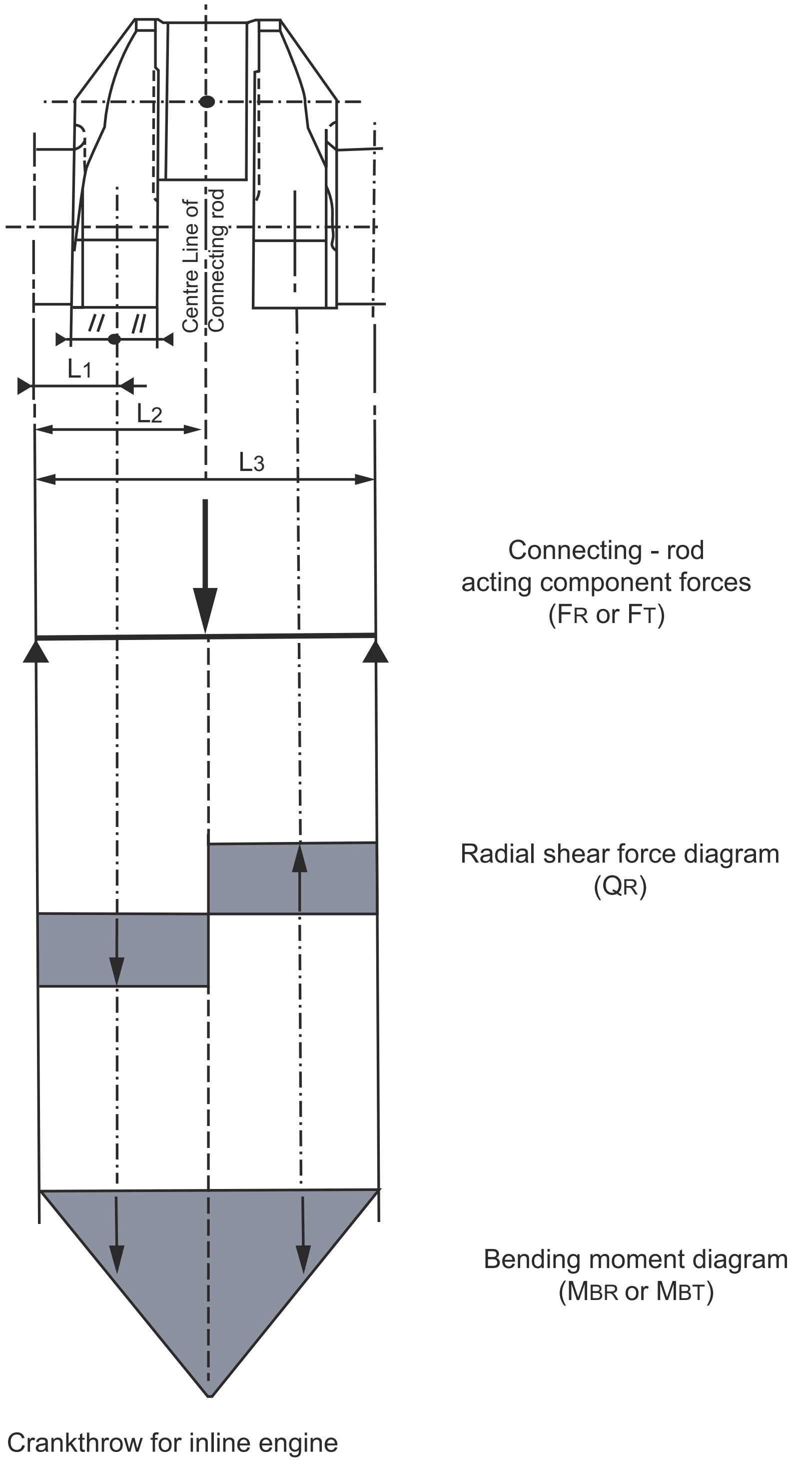


Figure 1.3.8 Stress concentration factors and stress distribution at the edges of oil drillings

3.5 Calculation of alternating stresses due to bending moments and radial forces – assumptions

3.5.1 The calculation is based on a statically determined system, composed of a single crankthrow supported in the centre of adjacent main journals and subject to gas and inertia forces. The bending length is taken as the length between the two main bearing midpoints (distance L_3, *see Figure 1.3.9 Bending moment and shear force for in-line engine crankthrows* and *Figure 1.3.10 Bending moment and shear force for V engine crankthrows*).

3.5.2 The bending moments, M_{BR} and M_{BT}, are calculated in the relevant section based on triangular bending moment diagrams due to the radial component F_R and tangential component F_T of the connecting-rod force, respectively (*see Figure 1.3.9 Bending moment and shear force for in-line engine crankthrows*). For crankthrows with two connecting-rods acting upon one crankpin the relevant bending moments are obtained by superposition of the two triangular bending moment diagrams according to phase (*see Figure 1.3.10 Bending moment and shear force for V engine crankthrows*).

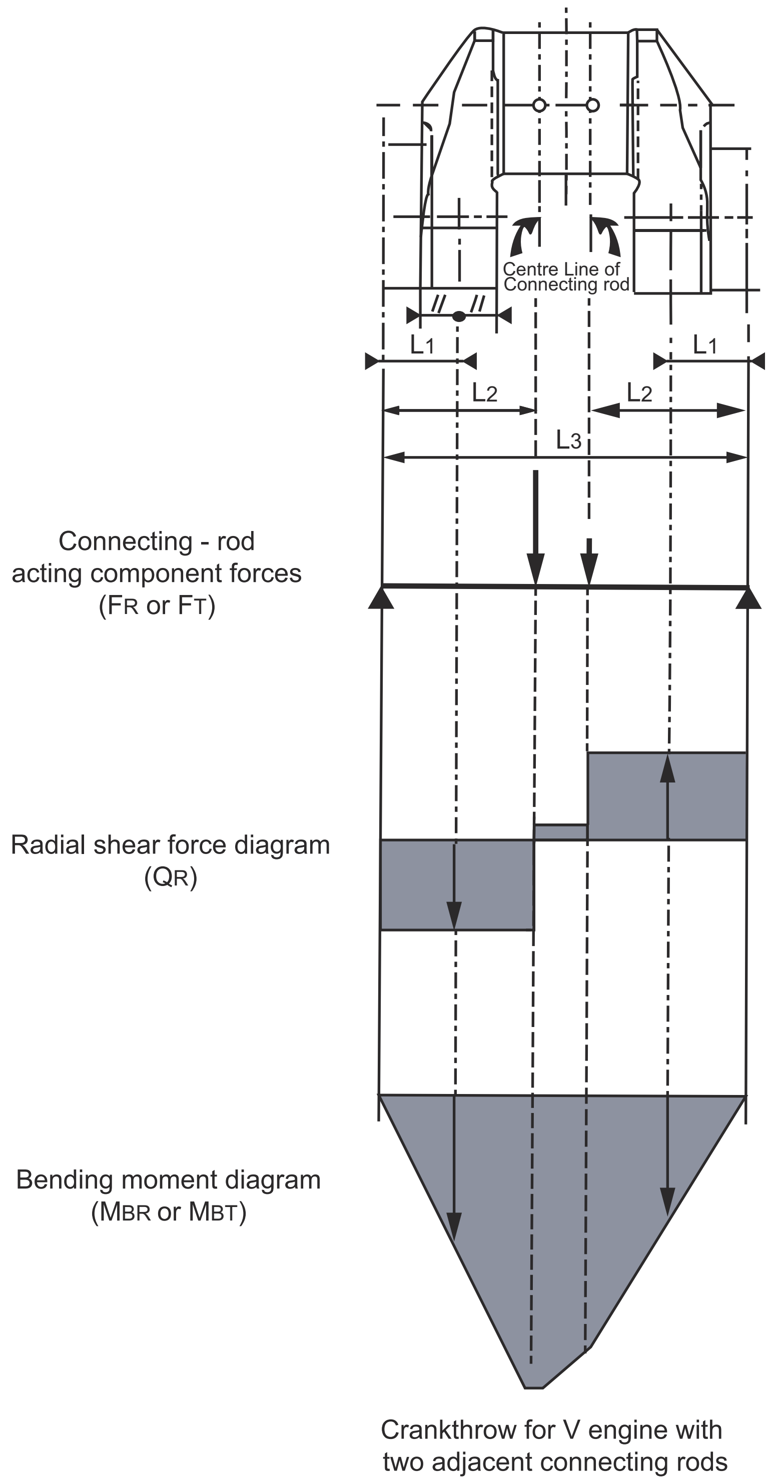


L_1 = Distance between main journal centreline and crankweb centre

L_2 = Distance between main journal centreline and connecting - rod centre

L_3 = Distance between two adjacent main journal centrelines

Figure 1.3.9 Bending moment and shear force for in-line engine crankthrows



L_1 = Distance between main journal centreline and crankweb centre

L_2 = Distance between main journal centreline and connecting - rod centre

L_3 = Distance between two adjacent main journal centrelines

Figure 1.3.10 Bending moment and shear force for V engine crankthrows

The bending moment M_{BRF} and the radial force Q_{RF} are taken as acting in the centre of the solid web (distance L_1) and are derived from the radial component of the connecting-rod force. The alternating bending and compressive stresses due to bending moments and radial forces are to be related to the cross-section of the crankweb. This reference section results from the web thickness W and the web width *B* (*see Figure 1.3.9 Bending moment and shear force for in-line engine crankthrows* and *Figure 1.3.4 Crank dimensions for crankshaft without overlap*,). Mean stresses are neglected.

3.5.4 The two relevant bending moments for bending acting on the outlet of crankpin oil bores are taken in the crankpin cross-section through the oil bore. *See*

- *Figure 1.3.5 Crankpin section through the oil bore*,
- *Figure 1.3.9 Bending moment and shear force for in-line engine crankthrows*, and
- *Figure 1.3.10 Bending moment and shear force for V engine crankthrows*.

M_{BRO} is the bending moment of the radial component of the connecting-rod force and M_{BTO} is the bending moment of the tangential component of the connecting-rod force. The alternating stresses due to these bending moments are to be related to the cross-sectional area of the axially bored crankpin. Mean bending stresses are neglected.

3.6 Calculation of bending stresses

3.6.1 The radial and tangential forces due to gas and inertia loads acting upon the crankpin at each connecting-rod position are to be calculated over one working cycle. Using the forces calculated over one working cycle and taking into account of the distance from the main bearing midpoint, the time curve of the bending moments, M_{BRF}, M_{BRO} and M_{BTO}, and radial forces, Q_{RF}, as defined in *Pt 10, Ch 1, 3.5 Calculation of alternating stresses due to bending moments and radial forces – assumptions 3.5.3* and *Pt 10, Ch 1, 3.5 Calculation of alternating stresses due to bending moments and radial forces – assumptions 3.5.4* are then calculated.

3.6.2 Nominal bending stresses are referred to the web bending modulus.

3.6.3 In case of V-type engines, the bending moments – progressively calculated from the gas and inertia forces – of the two cylinders acting on one crankthrow are superposed according to phase. Different designs (forked connecting-rod, articulated-type connecting-rod or adjacent connecting-rods) shall be taken into account.

3.6.4 Where there are cranks of different geometrical configurations in one crankshaft, the calculation is to cover all crank variants.

3.6.5 The decisive alternating values will then be calculated according to:

$$X_N = \pm\frac{1}{2}\left(X_{max} - X_{min}\right)$$

where

X_N is considered as the alternating force, moment or stress

X_{max} is the maximum value within one working cycle

X_{min} is the minimum value within one working cycle.

3.6.6 Nominal alternating bending and compressive stresses in a web cross-section are calculated as follows:

$$\sigma_{BFN} = \pm\frac{M_{BRFN}}{W_{eqw}}10^3\ K_e \text{ N/mm}^2$$

$$\sigma_{QFN} = \pm\frac{Q_{RFN}}{F}\ K_e \text{ N/mm}^2$$

where

$$M_{BRFN} = \pm\frac{1}{2}\left(M_{BRF\,max} - M_{BRF\,min}\right) \text{ Nm}$$

$$W_{eqw} = \frac{BW^2}{6} \text{ mm}^3$$

K_e = 0,8 for crosshead engines

= 1,0 for trunk piston engines

where

$Q_{RFN} = \pm\frac{1}{2}\left(Q_{RF\ max} - Q_{RF\ min}\right)$ N

F = BW mm^2

3.6.7 Nominal alternating bending stress in the outlet of the crankpin oil bore is calculated as follows:

$$\sigma_{BON} = \pm\frac{M_{BON}}{W_e} 10^3 \text{ N/mm}^2$$

where

M_{BON} is taken as the ½ range value $M_{BON} = \pm$ ½ $(M_{BOmax} - M_{BOmin})$ Nm

and

M_{BO} = $(M_{BTO} \cos\psi + M_{BRO} \sin\psi)$, ψ = angular position in degrees, *see Figure 1.3.5 Crankpin section through the oil bore*; and

M_{BRO} = bending moment of the radial component of the connecting-rod force

M_{BTO} = bending moment of the tangential component of the connecting-rod force

$$W_e = \frac{\pi}{32}\left(\frac{D^4 - D_{BH}{}^4}{D}\right) \text{ mm}^3$$

3.6.8 Alternating bending stresses for the crankpin fillet and journal fillet are calculated as follows:

(a) For the crankpin fillet:

$$\sigma_{BH} = \pm\left(\alpha_b\ \sigma_{BFN}\right) \text{ N/mm}^2$$

where

α_B is calculated according to *Pt 10, Ch 1, 3.8 Stress concentration factors 3.8.6.(a)*

(b) For the journal fillet:

$$\sigma_{BG} = \pm\left(\beta_B\, \sigma_{BFN} + \beta_Q\, \sigma_{QFN}\right) \text{ N/mm}^2$$

where

β_B is calculated according to *Pt 10, Ch 1, 3.8 Stress concentration factors 3.8.7.(a)*

β_Q is calculated according to *Pt 10, Ch 1, 3.8 Stress concentration factors 3.8.7.(b)*

3.6.9 Alternating bending stresses for the outlet of the crankpin oil bore are calculated as follows:

$$\sigma_{BO} = \pm\left(\gamma_B\ \sigma_{BON}\right) \text{ N/mm}^2$$

where

γ_B is calculated according to *Pt 10, Ch 1, 3.8 Stress concentration factors 3.8.8.(a)*

3.7 Calculation of torsional stresses

3.7.1 The nominal alternating torsional stress, τ_N, is to be taken into consideration. The value is to be derived from forced-damped vibration calculations of the complete dynamic system. Alternative methods will be given consideration. The engine designer is to advise the maximum level of alternating vibratory stress that is permitted (τ_a).

3.7.2 τ_a or τ_N(as applicable) is to be applied as a limiting value for the torsional vibration assessment required by *Pt 13, Ch 1 Torsional Vibration*.

3.7.3 Nominal alternating torsional stress is calculated as follows:

$$\tau_N = \pm\frac{M_{TN}}{W_P}10^3 \quad \text{N/mm}^2$$

where

$$M_{TN} = \pm\frac{1}{2}\left(M_{Tmax} - M_{Tmin}\right) \text{ Nm}$$

$$W_p = \frac{\pi}{16}\left(\frac{D_G{}^4 - D_{BH}{}^4}{D}\right) \text{ mm}^3 \text{ for the crankpin, or } W_p = \frac{\pi}{16}\left(\frac{D^4 - D_{BG}{}^4}{D_c}\right) \text{ mm}^3 \text{ for the journal}$$

τ_N is to be ascertained from assessment of the torsional vibration calculations where the maximum and minimum torques are determined for every mass point of the complete dynamic system and for the entire speed range by means of a harmonic synthesis of the forced vibrations from the first order up to and including the 15th order for 2-stroke cycle engines and from the 0,5th order up to and including the 12th order for 4-stroke cycle engines. Whilst doing so, allowance must be made for the damping that exists in the system and for unfavourable conditions (misfiring in one of the cylinders when no combustion occurs but only on the compression cycle). The speed step calculation shall be selected in such a way that any resonance found in the operational speed range of the engine shall be detected.

3.7.4 For the purpose of the crankshaft assessment, the nominal alternating torsional stress considered in calculations is to be the highest calculated value, according to the method described in *Pt 10, Ch 1, 3.7 Calculation of torsional stresses 3.7.3*, occurring at the most torsionally loaded mass point of the crankshaft system.

3.7.5 The approval of the crankshaft will be based on the installation having the largest nominal alternating torsional stress (but not exceeding the maximum figure specified by the engine manufacturer). For each installation it is to be ensured by calculation that the maximum approved nominal alternating torsional stress is not exceeded. *See Pt 13, Ch 1 Torsional Vibration*.

3.7.6 Alternating torsional stresses for the crankpin fillet, the journal fillet and the outlet of the crankpin oil bore are calculated as follows.

(a) Maximum alternating torsional stress in crankpin fillet:

$$\tau_H = \pm\left(\alpha_T \tau_N\right) \text{ N/mm}^2$$

where

α_T is calculated according to *Pt 10, Ch 1, 3.8 Stress concentration factors 3.8.6.(b)*.

(b) Maximum alternating torsional stress in the journal fillet (not applicable to semi-built crankshafts):

$$\tau_G = \pm\left(\beta_T \tau_N\right) \text{ N/mm}^2$$

where

β_T is calculated according to *Pt 10, Ch 1, 3.8 Stress concentration factors 3.8.7.(c)*.

(c) Maximum alternating torsional stress in the outlet of the crankpin oil bore:

$$\sigma_{TO} = \pm\left(\gamma_T \tau_N\right) \text{ N/mm}^2$$

where

γ_T is calculated according to *Pt 10, Ch 1, 3.8 Stress concentration factors 3.8.8.(b)*.

3.8 Stress concentration factors

3.8.1 Stress concentration factors (SCF) are to be calculated using the analytical formulae outlined in this Section.

3.8.2 Crankshaft variables to be used in calculating the geometric stress concentrations factors are shown in *Table 1.3.1 Crankshaft variables for SCF calculation*, their limits of applicability are shown in *Table 1.3.2 Crankshaft variable boundaries for analytical SCF calculation*.

3.8.3 Where the geometry of the crankshaft is outside the boundaries (*see Table 1.3.2 Crankshaft variable boundaries for analytical SCF calculation*) of the analytical SCF the calculation method detailed in Chapter 1 and Chapter 4 of the LR *Guidance*

Notes for Calculation of Stress Concentration Factors, Fatigue Enhancement Methods and Evaluation of Fatigue Tests for Crankshafts may be undertaken.

3.8.4 Where reliable experimental measurements and/or calculations are available, which can allow direct assessment of SCF, these can be used. The relevant documents and their analysis are to be submitted for consideration in order to demonstrate their equivalence. This is always to be performed when dimensions are outside the boundaries shown in *Table 1.3.2 Crankshaft variable boundaries for analytical SCF calculation*.

3.8.5 Chapters 1 and 4 of the LR *Guidance Notes for Calculation of Stress Concentration Factors, Fatigue Enhancement Methods and Evaluation of Fatigue Tests for Crankshafts* describe how finite element (FE) analyses can be used for the calculation of the SCF. Care needs to be taken to avoid mixing equivalent (von Mises) stresses and principal stresses.

Table 1.3.1 Crankshaft variables for SCF calculation

Variable	Function
r	$= R_H/D$ for crankpin fillet $= R_G/D$ for journal fillet
s	$= S/D$
w	$= W/D$ crankshafts with overlap $= W_{red}/D$ crankshafts without overlap
b	$= B/D$
d_o	$= D_O/D$
d_G	$= D_{BG}/D$
d_H	$= D_{BH}/D$
t_H	$= T_H/D$
t_G	$= T_G/D$

Table 1.3.2 Crankshaft variable boundaries for analytical SCF calculation

Lower bound	Variable	Upper bound
	s	$\leq 0,5$
$0,2 \leq$	w	$\leq 0,8$
$1,1 \leq$	b	$\leq 2,2$
$0,03 \leq$	r	$\leq 0,13$
$0 \leq$	d_G	$\leq 0,8$
$0 \leq$	d_H	$\leq 0,8$
$0 \leq$	d_o	$\leq 0,2$
Notes The lower bound of s can be extended down to large negative values provided that: • If calculated f(recess) < 1, then the factor f(recess) is not to be considered (f(recess) = 1) • If $s < -0,5$, then $f(s,w)$ and $f(r,s)$ are to be evaluated replacing actual value of s by $-0,5$.		

3.8.6 Crankpin SCF are calculated as follows:

(a) Bending

$$\alpha_B = 2,6914 \cdot f(s,w) \cdot f(w) \cdot f(b) \cdot f(r) \cdot f(d_G) \cdot f(d_H) \cdot f(\text{recess})$$

where

$f(s,w)$ = $-4{,}1883 + 29{,}2004w - 77{,}5925w^2 + 91{,}9454w^3 - 40{,}0416w^4 + (1 - s)(9{,}5440 - 58{,}3480w + 159{,}3415w^2 - 192{,}5846w^3 + 85{,}2916w^4) + (1 - s)^2(-3{,}8399 + 25{,}0444w - 70{,}5571w^2 + 87{,}0328w^3 - 39{,}1832w^4)$

$f(w)$ = $2{,}1790w^{0{,}7171}$

$f(b)$ = $0{,}684 - 0{,}0077b + 0{,}1473b^2$

$f(r)$ = $0{,}2081r^{(-0{,}5231)}$

$f(d_G)$ = $0{,}9993 + 0{,}27d_G - 1{,}0211d_G^2 + 0{,}5306d_G^3$

$f(d_H)$ = $0{,}9978 + 0{,}3145d_H - 1{,}5241d_H^2 + 2{,}4147d_H^3$

$f(\text{recess})$ = $1 + (t_H + t_G)(1{,}8 + 3{,}2s)$

(b) Torsion

$\alpha_T = 0{,}8 \cdot f(r,s) \cdot f(b) \cdot f(w)$

where

$f(r,s)$ = $r^{(-0{,}322 + 0{,}1015\,(1-s))}$

$f(b)$ = $7{,}8955 - 10{,}654b + 5{,}3482b^2 - 0{,}857b^3$

$f(w)$ = $w^{(-0{,}145)}$

3.8.7 Journal fillet SCF are calculated as follows (not applicable to semi-built crankshafts):

(a) Bending

$\beta_B = 2{,}7146 \cdot f_B(s,w) \cdot f_B(w) \cdot f_B(b) \cdot f_B(r) \cdot f_B(d_G) \cdot f_B(d_H) \cdot f(\text{recess})$

where

$f_B(s,w)$ = $-1{,}7625 + 2{,}9821w - 1{,}5276w^2 + (1 - s)(5{,}1169 - 5{,}8089w + 3{,}1391w^2) + (1 - s)^2(-2{,}1567 + 2{,}3297w - 1{,}2952w^2)$

$f_B(w)$ = $2{,}2422w^{0{,}7548}$

$f_B(b)$ = $0{,}5616 + 0{,}1197b + 0{,}1176b^2$

$f_B(r)$ = $0{,}1908r^{(-0{,}5568)}$

$f_B(d_G)$ = $1{,}0012 - 0{,}6441d_G + 1{,}2265d_G^2$

$f_B(d_H)$ = $1{,}0022 - 0{,}1903d_H + 0{,}0073d_H^2$

$f(\text{recess})$ = $1 + (t_H + t_G)(1{,}8 + 3{,}2s)$

(b) Compression due to the radial force

$\beta_Q = 3{,}0128 f_Q(s).f_Q(w).f_Q(b).f_Q(r).f_Q(d_H).f(\text{recess})$

where

$f_Q(s)$ = $0{,}4368 + 2{,}1630(1 - s) - 1{,}5212(1 - s)^2$

$f_Q(w)$ = $\dfrac{w}{0{,}0637 + 0{,}9369w}$

$f_Q(b)$ = $b^{-0{,}5}$

$f_Q(r)$ = $0{,}5331r^{(-0{,}2038)}$

$f_Q(d_H)$ = $0{,}9937 - 1{,}1949d_H + 1{,}7373d_H^2$

where

$f(\text{recess}) = 1 + (t_H + t_G)(1{,}8 + 3{,}2s)$

(c) Torsion

$\beta_T = \alpha_T$ if the diameters and fillet radii of crankpin and journal are the same, or

$\beta_T = 0{,}8 f(r,s).f(b).f(w)$ if crankpin and journal diameters and/or radii are of different sizes

where

$f(r,s)$, $f(b)$ and $f(w)$ are to be determined in accordance with *Pt 10, Ch 1, 3.8 Stress concentration factors 3.8.6.(b)*, however, the radius of the journal fillet is to be related to the journal diameter: $r = \frac{R_G}{D_G}$

3.8.8 Crankpin oil bore SCF for radially drilled oil holes are calculated as follows:

(a) Bending

$\gamma_B = 3 - 5{,}88 d_o + 34{,}6 d_o^2$

(b) Torsion

$\gamma_T = 4 - 6 d_o + 30 d_o^2$

3.9 Additional bending stress

3.9.1 In addition to the alternating bending stresses in fillets (*see Pt 10, Ch 1, 3.6 Calculation of bending stresses 3.6.6*) further bending stresses due to misalignment and bedplate deformation as well as due to axial and bending vibrations are to be considered by applying σ_{add} as given by *Table 1.3.3 Additional bending stresses*

Table 1.3.3 Additional bending stresses

Type of engine	σ_{add}
Crosshead engines	± 30 N/mm^2 (*see* Note 1)
Trunk piston engines	± 10 N/mm^2
Note 1. The additional stress of ±30 N/mm^2 is composed of two components: (a) an additional stress of ±20 N/mm^2 resulting from axial vibration (b) an additional stress of ±10 N/mm^2 resulting from misalignment/bedplate deformation	

3.9.2 It is recommended that a value of ±20 N/mm^2 be used for the axial vibration component for assessment purposes where axial vibration calculation results of the complete dynamic system (engine/shafting/gearing/propeller) are not available. Where axial vibration calculation results of the complete dynamic system are available, the calculated figures can be used instead.

3.10 Equivalent alternating stress

3.10.1 In the fillets, bending and torsion lead to two different biaxial stress fields which can be represented by a von Mises equivalent stress with the additional assumptions that bending and torsion stresses are time phased and the corresponding peak values occur at the same location (*see Figure 1.3.7 Stress concentration factors in crankshaft fillets*). As a result the equivalent alternating stress is to be calculated for the crankpin fillet as well as for the journal fillet by using the von Mises criterion.

3.10.2 At the oil hole outlet, bending and torsion lead to two different stress fields which can be represented by an equivalent principal stress equal to the maximum of principal stress resulting from combination of these two stress fields with the assumption that bending and torsion are time phased (*see Figure 1.3.8 Stress concentration factors and stress distribution at the edges of oil drillings*).

3.10.3 The above two different ways of equivalent stress evaluation both lead to stresses which can be compared to the same fatigue strength value of crankshaft assessed according to the von Mises criterion.

3.10.4 Equivalent alternating stress, σ_v, is defined as:

(a) For the crankpin fillet:

$$\sigma_V = \pm\sqrt{(\sigma_{BH} + \sigma_{add})^2 + 3\tau_H{}^2} \quad \text{N/mm}^3$$

(b) For the journal fillet:

$$\sigma_V = \pm\sqrt{(\sigma_{BG} + \sigma_{add})^2 + 3\tau_G{}^2} \quad \text{N/mm}^2$$

(c) For the outlet of crankpin oil bore:

$$\sigma_V = \pm\frac{1}{3}\sigma_{BO}\left[1 + 2\sqrt{1 + \frac{9}{4}\left(\frac{\sigma_{TO}}{\sigma_{BO}}\right)^2}\right] \quad \text{N/mm}^2$$

3.11 Fatigue strength

3.11.1 The fatigue strength is to be understood as that value of equivalent alternating stress (von Mises) which a crankshaft can permanently withstand at the most highly stressed points. The fatigue strength can be evaluated by means of the following formulae:

(a) Related to the crankpin diameter:

$$\sigma_{DW} = \pm K(0{,}42\sigma_B + 39{,}3)\left[0{,}264 + 1{,}073D^{-0,2} + \frac{785 - \sigma_B}{4900} + \frac{196}{\sigma_B}\sqrt{\frac{1}{R_X}}\right]\text{N/mm}^2$$

with

R_X = R_H in the fillet area

R_X = $D_o/2$ in the oil bore area

(b) Related to the journal diameter:

$$\sigma_{DW} = \pm K(0{,}42\sigma_B + 39{,}3)\left[0{,}264 + 1{,}073D_G{}^{-0,2} + \frac{785 - \sigma_B}{4900} + \frac{196}{\sigma_B}\sqrt{\frac{1}{R_G}}\right]\text{N/mm}^2$$

where

K = K_1K_2

K_1 = fatigue endurance factor appropriate to the manufacturing process

= 1,05 for continuous grain flow forged or drop-forged crankshafts

= 1,0 for free form forged crankshafts (without continuous grain flow)

= 0,93 for cast steel crankshafts with cold rolling treatment in fillet area manufactured by companies using a LR approved cold rolling process

K_2 = fatigue enhancement factor for surface treatment. These treatments are to be applied to the fillet radii

A value for K_2 will be assigned upon application by the engine designers. Full details of the process, together with the results of full scale fatigue tests will be required to be submitted for consideration. *See* Chapter 2 of the LR *Guidance notes for the Calculation of Stress Concentration Factors, Fatigue Enhancement Methods and Evaluation of Fatigue Tests for Crankshafts*. Alternatively, the following values may be taken (surface hardened zone to include fillet radii):

K_2 = 1,15 for induction hardened

= 1,25 for nitrided

Where a value of K_1 or K_2 greater than unity is to be applied, details of the manufacturing process are to be submitted. An enhanced K_1 factor will be considered, subject to special approval of the manufacturing specification. *See Materials and Qualification Procedures for Ships, Book E, Procedure MQPS 5-2*.

3.11.2 The formulae in *Pt 10, Ch 1, 3.11 Fatigue strength 3.11.1* are subject to geometry limits. The junction of the oil hole with the crankpin or main journal surface is to be formed with an adequate radius and smooth surface finish down to a minimum depth equal to 1,5 times the oil bore diameter and for calculation purposes R_H, R_G or R_X are to be taken as not less than 2 mm.

3.11.3 Fatigue strength calculations or, alternatively, fatigue test results determined by experiment based either on full size crankthrow (or crankshaft), or on specimens taken from a full size crankthrow, may be required to demonstrate acceptability. The experimental procedure for fatigue evaluation of specimens and fatigue strength of crankshaft assessment are to be submitted for approval by LR. The procedure is to include as a minimum: method, type of specimens, number of specimens (or crankthrows), number of tests, survival probability, and confidence number. *See also* Chapter 2 of the LR *Guidance Notes for the Calculation of Stress Concentration Factors, Fatigue Enhancement Methods, and Evaluation of Fatigue Tests for Crankshafts.*

3.11.4 When journal diameter is equal or larger than the crankpin diameter, the outlets of main journal oil bores are to be formed in a similar way to the crankpin oil bores, otherwise separate fatigue strength calculations or, alternatively, fatigue test results may be required.

3.11.5 Only surface treatment processes approved by LR are permitted. Guidance for calculation of surface treated fillets and oil bore outlets is presented in Chapter 3 of the LR *Guidance Notes for the Calculation of Stress Concentration Factors, Fatigue Enhancement Methods, and Evaluation of Fatigue Tests for Crankshafts*.

3.12 Acceptability criteria

3.12.1 The sufficient dimensioning of a crankshaft is confirmed by a comparison of the equivalent alternating stress and the fatigue strength. The acceptability factor, Q, is to be greater than or equal to 1,15 for the crankpin fillet, and the journal fillet and the outlet of crankpin oil bore:

$$Q = \frac{\sigma_{DW}}{\sigma_V}$$

3.13 Shrink fit of semi-built crankshafts

3.13.1 The following formulae are applicable to crankshafts assembled by shrinking main journals into the crankwebs, *see also Figure 1.3.6 Crankthrow of semi-built crankshaft*;.

3.13.2 In general, the radius of transition, R_G, between the main journal diameter, D_G, and the shrink diameter, D_S, is to be not less than $0{,}015D_G$ or $0{,}5(D_S - D_G)$ where the greater value is to be considered.

3.13.3 Deviations from these parameters will be specially considered.

3.13.4 The maximum permissible internal diameter in the journal pin is to be calculated in accordance with the following formula, this condition serves to avoid plasticity in the hole of the journal pin:

$$D_{BG} = D_S\sqrt{1 - \frac{4000 S_R M_{max}}{\mu\, \pi\, D_S^{\,2} L_S \sigma_{SP}}} \text{ mm}$$

where

S_R = safety factor against slipping; however, a value of not less than 2 is to be taken unless documented by experiments.

M_{max} = absolute maximum value of the torque M_{Tmax} in accordance with *Pt 5, Ch 2, 3.7 Calculation of torsional stresses 3.7.3*, in Nm

μ = coefficient for static friction; however, a value of not greater than 0,2 is to be taken unless documented by experiments.

3.13.5 The actual oversize Z of the shrink fit must be within the limits Z_{min} and Z_{max} calculated in accordance *Pt 10, Ch 1, 3.13 Shrink fit of semi-built crankshafts 3.13.6* and *Pt 10, Ch 1, 3.13 Shrink fit of semi-built crankshafts 3.13.7*. When *Pt 10, Ch 1, 3.13 Shrink fit of semi-built crankshafts 3.13.5* cannot be complied with, then the calculated values of Z_{min} and Z_{max} are not applicable due to multizone-plasticity problems. In such cases Z_{min} and Z_{max} are to be established from FEM calculations.

3.13.6 The minimum required diametral interference is to be taken as the greater of:

$$Z_{min} \geq \frac{\sigma_{SW} D_S}{E_m} \quad \text{mm}$$

and

$$Z_{min} \geq \frac{4000}{\mu\pi} \frac{S_R M_{max}}{E_m D_S L_S} \frac{1 - Q_A{}^2 Q_S{}^2}{\left(1 - Q_A{}^2\right)\left(1 - Q_S{}^2\right)} \quad \text{mm}$$

where

Q_A = web ratio, $Q_A = \frac{D_S}{D_A}$

Q_S = shaft ratio, $Q_S = \frac{D_{BG}}{D_S}$

3.13.7 The maximum diametral interference is not to be greater than:

$$Z_{max} \leq D_S \left(\frac{\sigma_{SW}}{E_m} + \frac{0{,}8}{1000} \right) \text{mm}$$

This condition serves to restrict the shrinkage induced mean stress in the fillet.

3.13.8 Reference marks are to be provided on the outer junction of the crankwebs with the journals.

■ *Section 4*
Electronically controlled engines

4.1 Scope

4.1.1 The requirements of this Section are applicable to engines for propulsion, auxiliary or emergency power purposes with programmable electronic systems implemented and used to control fuel injection timing and duration, and which may also control combustion air or exhaust systems. The requirements of this Section also apply to programmable electronic systems used to control other functions (e.g. starting and control air, cylinder lubrication, etc.) where essential for the operation of the engine.

4.1.2 These engines may be of the crosshead or trunk piston type. They generally have no direct camshaft driven fuel systems, but have common rail fuel/hydraulic arrangements and may have hydraulic actuating systems for the functioning of the exhaust systems.

4.1.3 The operation of these engines relies on the effective monitoring of a number of parameters such as crank angle, engine speed, temperatures and pressures using programmable electronic systems to provide the services essential for the operation of the engine such as fuel injection, air inlet, exhaust and speed control.

4.1.4 Details of proposals to deviate from the requirements of this Section are to be submitted and will be considered on the basis of a technical justification produced by the Enginebuilder.

4.1.5 Each engine is to be configured for the specified performance and is to satisfy the relevant requirements for propulsion, auxiliary or emergency engines.

4.1.6 During the life of the engine details of any proposed changes to control, alarm, monitoring or safety systems which may affect safety and the reliable operation of the engine are to be submitted to LR for approval.

4.2 Risk-based analysis

4.2.1 An analysis is to be carried out in accordance with relevant standards acceptable to LR to demonstrate compliance with the applicable requirements of this sub- Section appropriate to the engine application. The analysis is to be a risk-based consideration of engine operation and craft and personnel safety, and is to demonstrate adequate risk mitigation through fault tolerance and/or reliability in accordance with the specified criteria in *Pt 10, Ch 1, 4.2 Risk-based analysis 4.2.2* to *Pt 10, Ch 1, 4.2 Risk-based analysis 4.2.4* relevant to the engine application.

4.2.2 For craft with a single main propulsion engine, a Failure Mode and Effects Analysis (FMEA), or alternative recognised analysis of system reliability, is to be carried out and is to demonstrate that an electronic control system failure:

(a) will not result in the loss of the ability to provide the services essential for the operation of the engine, *see Pt 16, Ch 1, 2.5 Control systems 2.5.10* and *Pt 16, Ch 1, 2.12 Additional requirements for wireless data communication links 2.12.2*;
(b) will not affect the normal operation of the services essential for the operation of the engine other than those services dependent upon the failed part, *see Pt 16, Ch 1, 2.13 Programmable electronic systems – Additional requirements for essential services and safety critical systems 2.13.4* and *Pt 16, Ch 1, 2.13 Programmable electronic systems – Additional requirements for essential services and safety critical systems 2.13.4*; and
(c) will not leave either the engine, or any equipment or machinery associated with the engine, or the craft in an unsafe condition, *see Pt 16, Ch 1, 2.3 Alarm systems 2.3.14*, *Pt 16, Ch 1, 2.4 Safety systems, general requirements 2.4.5*, *Pt 16, Ch 1, 2.5 Control systems 2.5.4*, *Pt 16, Ch 1, 2.10 Programmable electronic systems – General requirements 2.10.3*, *Pt 16, Ch 1, 2.10 Programmable electronic systems – General requirements 2.10.4* and *Pt 16, Ch 1, 2.13 Programmable electronic systems – Additional requirements for essential services and safety critical systems 2.13.5*.

4.2.3 A risk-based analysis is to be carried out for:

(a) main engines on craft with multiple main engines or other means of providing propulsion power; and/or
(b) auxiliary engines intended to drive electric generators forming the craft's main source of electrical power or otherwise providing power for essential services.

The analysis is to demonstrate that adequate hazard mitigation has been incorporated in electronically controlled engine systems or the overall craft installation with respect to personnel safety and providing propulsion power and/or power for essential services for the safety of the craft. Arrangements satisfying the criteria of *Pt 10, Ch 1, 4.2 Risk-based analysis 4.2.2* will also be acceptable

4.2.4 For engines for emergency power purposes, a risk-based analysis is to be carried out to demonstrate that the design incorporates adequate hazard mitigation, such that the likelihood of an electronic control system failure, resulting in the loss of the ability to provide emergency power when required, has been reduced to a level considered acceptable by LR, and that means are provided to detect failures and permit personnel to restore engine availability to operate on demand. Failures which would result in engine failure and/or damage or loss of availability are to be identified, and the report is to include documentation of:

(a) component reliability evidence;
(b) failure detection and alarms; and
(c) failure response required to restore engine availability and maintain personnel safety.

4.2.5 The risk-based analysis report is to:

(a) Identify the standards used for analysis and system design;
(b) Identify the engine, its purpose and the associated objectives of the analysis;
(c) Identify any assumptions made in the analysis;
(d) Identify the equipment, system or sub-system and the mode of operation;
(e) Identify potential failure modes and their causes.
(f) Evaluate the local effects (e.g. fuel injection failure) and the effects on the system as a whole (e.g. loss of propulsion power) of each failure mode;
(g) Identify measures for reducing the risks associated with each failure mode (e.g. system design, failure detection and alarms, redundancy, quality control procedures for sourcing, manufacture and testing, etc.); and
(h) Identify trials and testing necessary to prove conclusions.

4.2.6 At sub-system level, it is acceptable to consider failure of equipment items and their functions, e.g. failure of a pump to produce flow or pressure head. It is not required that the failure of components within that pump be analysed, and failure need only be dealt with as a cause of failure of the pump.

4.3 Control engineering systems

4.3.1 Control, alarm, monitoring, safety and programmable electronic systems are to comply with *Pt 16, Ch 1 Control Engineering Systems* as applicable.

4.3.2 The engine control, alarm monitoring and safety systems are to be configured to comply with the relevant requirements (e.g. operating profile, alarms, shutdowns, etc.) of this Chapter and *Pt 16, Ch 1 Control Engineering Systems* for an engine for main, auxiliary or emergency power purposes. Details of the engine configuration are to be submitted for consideration *see Pt 10, Ch 1, 1.4 Submission requirements 1.4.2*.

4.4 Software

4.4.1 Software lifecycle activities are to be carried out in accordance with an acceptable quality management system, *see Pt 16, Ch 1, 2.13 Programmable electronic systems – Additional requirements for essential services and safety critical systems 2.13.2* and *Pt 16, Ch 1, 2.13 Programmable electronic systems – Additional requirements for essential services and safety critical systems 2.13.7*.

4.4.2 Appropriate safety related processes, methods, techniques and tools are to be applied to software development and maintenance by the Enginebuilder. Selection and application of techniques and measures in accordance with Annex A of IEC 61508-3, *Functional safety of electrical/ electronic/programmable electronic systems: Software requirements*, or other relevant standards or codes acceptable to LR, will generally be acceptable.

4.4.3 To demonstrate compliance with *Pt 10, Ch 1, 4.4 Software 4.4.1* and *Pt 10, Ch 1, 4.4 Software 4.4.2*:

(a) software quality plans and safety evidence are to be submitted for consideration, *see Pt 10, Ch 1, 1.4 Submission requirements 1.4.2*; and

(b) an assessment inspection of the Enginebuilder's completed development is to be carried out by LR. The inspection is to be tailored to verify application of the standards and codes used in software safety assurance accepted by LR.

■ *Section 5*
Construction and welded structures

5.1 Crankcases

5.1.1 Crankcases and their doors are to be of robust construction to withstand anticipated crankcase pressures that may arise during a crankcase explosion, taking into account the installation of explosion relief valves required by *Pt 10, Ch 1, 10 Safety arrangements*, and the doors are to be securely fastened so that they will not be readily displaced by a crankcase explosion.

5.2 Welded joints

5.2.1 Bedplates and major components of engine structures are to be made with a minimum number of welded joints.

5.2.2 Double welded butt joints are to be adopted wherever possible in view of their superior fatigue strength.

5.2.3 Girder and frame assemblies should, so far as possible, be made from one plate or slab, shaped as necessary, rather than by welding together a number of small pieces.

5.2.4 Steel castings are to be used for parts which would otherwise require complicated weldments.

5.2.5 Care is to be taken to avoid stress concentrations such as sharp corners and abrupt changes in section.

5.2.6 Joints in parts of the engine structure which are stressed by the main gas or inertia loads are to be designed as continuous full strength welds and for complete fusion of the joint. They are to be so arranged that, in general, welds do not intersect, and that welding can be effected without difficulty and adequate inspection can be carried out. Abrupt changes in plate section are to be avoided and where plates of substantially unequal thickness are to be butt welded, the thickness of the heavier plate is to be gradually tapered to that of the thinner plate. Tee joints are to be made with full bevel or equivalent weld preparation to ensure full penetration.

5.2.7 In single plate transverse girders the castings for main bearing housings are to be formed with web extensions which can be butt welded to the flange and vertical web plates of the girder. Stiffeners in the transverse girder are to be attached to the flanges by full penetration welds.

5.3 Materials and construction

5.3.1 Plates, sections, forgings and castings are to be of welding quality in accordance with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials, July 2021*, and with a carbon content generally not exceeding 0,23 per cent. Steels with higher carbon contents may be approved subject to satisfactory results from welding procedure tests.

5.3.2 Welding is to be carried out in accordance with the requirements of *Rules for the Manufacture, Testing and Certification of Materials, July 2021 Ch 13 Requirements for Welded Construction*, using welding procedures and welders that have been

qualified in accordance with *Rules for the Manufacture, Testing and Certification of Materials, July 2021 Ch 12 Welding Qualifications*s.

5.3.3 Before welding is commenced the component parts of bedplates and framework are to be accurately fitted and aligned.

5.3.4 The welding is to be carried out in positions free from draughts and is to be downhand (flat) wherever practicable. Welding consumables are to be suitable for the materials being joined. Preheating is to be adopted when heavy plates or sections are welded. The finished welds are to have an even surface and are to be free from undercutting.

5.3.5 Welds attaching bearing housings to the transverse girders are to have a smooth contour and, if necessary, are to be made smooth by grinding.

5.4 Post-weld heat treatment

5.4.1 Bedplates are to be given a stress relieving heat treatment except engine types where the bedplate as a whole is not subjected to direct loading from the cylinder pressure. For these types, only the transverse girder assemblies need be stress relieved.

5.4.2 Stress relieving is to be carried out by heating the welded structure uniformly and slowly to a temperature between 580°C and 620°C, holding that temperature for not less than one hour per 25 mm of maximum plate thickness and thereafter allowing the structure to cool slowly in the furnace.

5.4.3 Omission of post-weld heat treatment of bedplates and their sub-assemblies will be considered on application by the engine builder with supporting evidence in accordance with *Ch 13, 2.10 Post-weld heat treatment 2.10.6* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2021*.

5.5 Inspection

5.5.1 Welded engine structures are to be examined during fabrication, special attention being given to the fit of component parts of major joints prior to welding.

5.5.2 Inspection of welds is to be in accordance with the requirements of *Ch 13, 1.11 Non-destructive examination of welds* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2021*.

5.5.3 Welds in transverse girder assemblies are to be crack detected by an approved method to the satisfaction of the Surveyors. Other joints are to be similarly tested if required by the Surveyors.

■ *Section 6*
Turning gear

6.1 General requirements

6.1.1 Turning gear is to be provided for all engines to facilitate operating and maintenance regimes as required by the manufacturer.

6.1.2 The turning gear for all main propulsion engines is to be power-driven and is to be continuously rated at a value to ensure protection to the weakest part of the machinery. Alternative proposals may be made subject to special consideration.

6.1.3 The turning gear for auxiliary engines may be hand operated (manual) except where this is not practicable, in which case the provision of *Pt 10, Ch 1, 6.1 General requirements 6.1.2* is to be complied with.

6.1.4 The turning gear for all engines is to be fitted with safety interlocks which prevent engine operation when engaged, *see Pt 9, Ch 1, 4.8 Machinery interlocks*. Indication of engaged/not engaged is to be provided at all start positions.

6.1.5 The remote control device of power-driven turning gear is to be so designed that power is removed from the turning gear when the operating switch is released.

6.1.6 Means are to be provided to secure the turning gear when disengaged.

6.1.7 Overload protection arrangements are to be provided to prevent damage to the electric motor and the turning gear train.

■ *Section 7* Control and monitoring of main, auxiliary and emergency engines

7.1 General

7.1.1 The Control and Monitoring systems are to comply with the requirements of *Pt 16 Control and Electrical Engineering*.

7.1.2 Oil mist detection or bearing temperature monitoring (or equivalent device in accordance with SOLAS II-1, *Regulation 47 - Fire precautions*, 47.2) fitted as required by *Pt 10, Ch 1, 10.8 Oil mist detection 10.8.1* are to operate as follows:

(a) For trunk piston engines automatic shutdown of the engine is to occur when oil mist or high bearing temperature is detected.
(b) For crosshead engines, automatic slow-down is to occur when oil mist or high bearing temperature is detected.
(c) Where arrangements are made to override the automatic shutdown due to high oil mist or bearing temperature, the override is to be independent of other overrides.
(d) Where the bearing temperature monitoring method is chosen, all bearings in the crankcase are to be monitored where practicable, e.g. main, crankpin, crosshead.
(e) Where engine bearing temperature monitors or equivalent devices in accordance with SOLAS II-1, *Regulation 47 - Fire precautions*, 47.2 are provided for the prevention of the build-up of oil mist that may lead to a potentially explosive condition within the crankcase, details are to be submitted for consideration. The submission is to demonstrate that the arrangements are equivalent to those provided by oil mist detection, *see Pt 10, Ch 1, 10.8 Oil mist detection 10.8.15*.

Where required, for each trunk piston engine, one oil mist detector (or engine bearing temperature monitoring system or equivalent device) having two independent outputs for initiating the alarm and shutdown would satisfy the requirement for independence between alarm and shutdown systems.

7.1.3 All main and auxiliary engines intended for essential services are to be provided with means of indicating the lubricating oil pressure supply to them. Where such engines are of more than 220 kW, audible and visual alarms are to be fitted to give warning of an appreciable reduction in pressure of the lubricating oil supply. Further, these alarms are to be actuated from the outlet side of any restrictions, such as filters, coolers, etc.

7.2 Main engine governors

7.2.1 An efficient governor is to be fitted to each main engine so adjusted that the speed does not exceed that for which the engine is to be classed by more than 15 per cent.

7.2.2 Engines coupled to electrical generators that are the source of power for main electric propulsion are to comply with the requirements for electrical generator engines in respect of governors and overspeed protection devices.

7.2.3 When electronic speed governors of main internal combustion engines form part of a remote control system, they are to comply with the following conditions:

(a) If lack of power to the governor may cause changes in the present speed and direction of thrust of the propeller, which consequently compromise safe operation of the vessel, then backup power supply is to be provided;
(b) Local control of the engines is always to be possible. A means to effect safe transfer of control to the local control position and then control the engine is to be available in all normal and reasonably foreseeable abnormal conditions;
(c) In addition, electronic speed governors and their actuators are to be type approved in accordance with LR's Type Approval System Test Specification Number 1.

7.3 Auxiliary and emergency engine governors

7.3.1 Prime movers for driving generators of the main and emergency sources of electrical power are to be fitted with a speed governor which will prevent transient frequency variations in the electrical network in excess of ±10 per cent of the rated frequency, with a recovery time to steady state conditions not exceeding 5 seconds, when the maximum electrical step load is switched on or off.

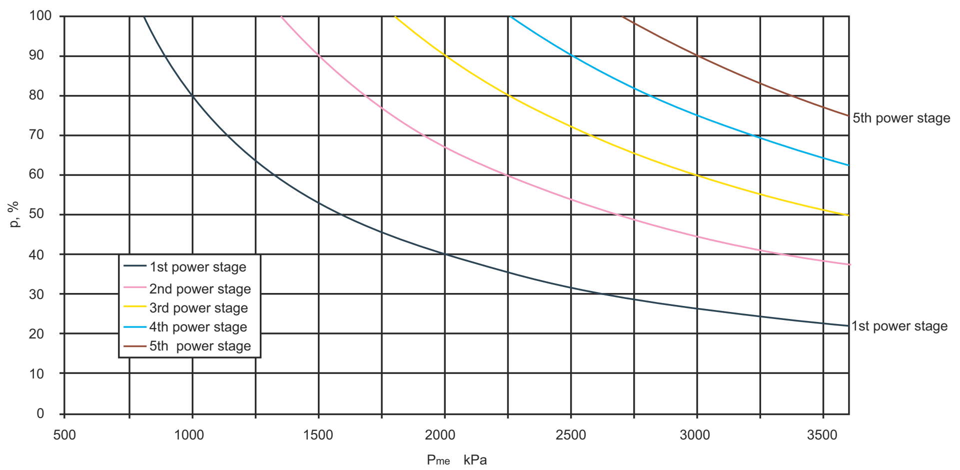
7.3.2 In the case when a step load equivalent to the rated output of a generator is switched off, a transient speed variation in excess of 10 per cent of the rated speed may be acceptable, provided that this does not cause the intervention of the overspeed device as required by *Pt 10, Ch 1, 7.4 Overspeed protective devices*.

7.3.3 At all loads between no load and rated power, the permanent speed variation should not be more than ±5 per cent of the rated speed.

7.3.4 Prime movers are to be selected in such a way that they will meet the load demand within the ship's power distribution system. Application of electrical load should be possible with two load steps and must be such that prime movers, running at no load, can suddenly be loaded to 50 per cent of the rated power of the generator followed by the remaining 50 per cent after an interval sufficient to restore the speed to steady state. Steady state conditions should be achieved in not more than 5 seconds. Steady state conditions are those at which the envelope of speed variation does not exceed +1 per cent of the declared speed at the new power.

7.3.5 Application of electrical load in more than two load steps can only be permitted if the conditions within the ship's power distribution system permit the use of such prime movers which can only be loaded in more than two load steps (*see Figure 1.7.1 Reference values for maximum possible sudden power increase (four-stroke engines)*) and provided that this is already allowed for at the design stage. This is to be verified in the form of system specifications to be approved and to be demonstrated at ship's trials. In this case, due consideration is to be given to:

(a) The power required for the electrical equipment to be automatically switched on after blackout and to the sequence in which it is connected.
(b) Where generators are to be operated in parallel and where the power has to be transferred from one generator to another in the event of any one generator being switched off.



P_{me} : mean effective pressure at declared power

P : power increase referred to declared power at site conditions

Figure 1.7.1 Reference values for maximum possible sudden power increase (four-stroke engines)

7.3.6 Emergency generator sets are to comply with the requirements of *Pt 10, Ch 1, 7.3 Auxiliary and emergency engine governors 7.3.1* to *Pt 10, Ch 1, 7.3 Auxiliary and emergency engine governors 7.3.3* even when:

(a) their total consumer load is applied suddenly; or
(b) their total consumer load is applied in steps, subject to:

- the total load being supplied within 45 seconds of power failure on the main switchboard;
- the maximum step load being declared and demonstrated;
- the power distribution system being designed such that the declared maximum step loading is not exceeded; and
- the compliance of time delays and loading sequence with the above being demonstrated at ship's trials.

7.3.7 For a.c. generating sets operating in parallel, the governing characteristics of the prime movers shall be such that within the limits of 20 per cent and 100 per cent total load, the load on any generating set will not normally differ from its proportionate share of the total load by more than 15 per cent of the rated power of the largest machine, or 25 per cent of the rated power of

the individual machine in question, whichever is the less. For an a.c. generating set intended to operate in parallel, facilities are to be provided to adjust the governor sufficiently finely to permit an adjustment of load not exceeding 5 per cent of the rated load at normal frequency.

7.3.8 For generator set voltage control requirements *see Pt 16, Ch 2, 9.4 Generator control*.

7.3.9 For quality of power supplies (QPS) requirements *see Pt 16, Ch 2, 1.8 Quality of power supplies*.

7.4 Overspeed protective devices

7.4.1 Each main engine developing 220 kW or over which can be declutched or which drives a controllable pitch propeller, also each auxiliary engine developing 220 kW and over for driving an electric generator, is to be fitted with an approved overspeed protective device.

7.4.2 The overspeed protective device, including its driving mechanism, is to be independent of the governor required by *Pt 10, Ch 1, 7.2 Main engine governors* or *Pt 10, Ch 1, 7.3 Auxiliary and emergency engine governors* and is to be so adjusted that the speed does not exceed that for which the engine and its driven machinery are to be classed by more than 20 per cent for main engines and 15 per cent for auxiliary engines.

7.5 Unattended machinery

7.5.1 Where main and auxiliary engines are fitted with automatic or remote controls so that under normal operating conditions they do not require any manual intervention by the operators, they are to be provided with the alarms and safety arrangements required by *Pt 10, Ch 1, 7.5 Unattended machinery* to *Pt 10, Ch 1, 7.7 Auxiliary engines* as appropriate. Alternative arrangements which provide equivalent safeguards will be considered.

7.5.2 Where machinery is arranged to start automatically or from a remote control station, interlocks are to be provided to prevent start-up under conditions, which could cause a hazard to the machinery and personnel.

7.5.3 Where machinery specified in this Section is required to be provided with a standby pump, the standby pump is to start automatically if the discharge pressure from the working pumps falls below a predetermined value.

7.5.4 Where a first stage alarm together with a second stage alarm and automatic shutdown of machinery are required by in the relevant Tables of this Section and, the sensors and circuits utilised for the second stage alarm and automatic shutdown are to be independent of those required for the first stage alarm.

7.5.5 Means are to be provided to prevent leaks from high pressure fuel oil injection piping for main and auxiliary engines dripping or spraying onto hot surfaces or into machinery air inlets. Such leakage is to be collected and, where practicable, led to a collector tank(s) fitted in a safe position. An alarm is to be provided to indicate that leakage is taking place. These requirements may also be applicable to high pressure hydraulic oil piping depending upon the location.

7.6 Engines for propulsion purposes

7.6.1 Alarms and safeguards are indicated in and *Pt 10, Ch 1, 7.6 Engines for propulsion purposes 7.6.2* to *Pt 10, Ch 1, 7.6 Engines for propulsion purposes 7.6.8* and *Table 1.7.1 Engines for propulsion purposes: alarms and safeguards slow-downs* and *Table 1.7.2 Engines for propulsion purposes: Automatic shutdowns*.

Table 1.7.1 Engines for propulsion purposes: alarms and safeguards slow-downs

Item	Alarm	Note
Lubricating oil sump level	Low	Engines (and gearing if fitted)
Lubricating oil inlet pressure*++	1st stage Low++	Engines (and gearing if fitted) Slow-down
Lubricating oil inlet temperature*	High	Engines (and gearing if fitted)
Lubricating oil filters differential pressure	High	-
Activation of oil mist detection arrangements (or activation of the temperature monitoring systems or equivalent devices of: - the engine main, crank and crosshead bearing oil outlet; or - the engine main, crank and crosshead bearing)	High	For crosshead engines, automatic slow-down. For trunk-piston engines, *see Table 1.7.2 Engines for propulsion purposes: Automatic shutdowns*. *See also Pt 10, Ch 1, 7.1 General 7.1.2*
Cylinder lubricator flow	Low	One sensor per lubricator unit on crosshead engines. Slow-down.
Thrust bearing temperature*	High	Slow-down
Piston coolant inlet pressure	Low	If a separate system. Slow-down
Piston coolant outlet temperature*	High	Per cylinder (if a separate system). Slow-down
Piston coolant outlet flow*	Low	Per cylinder (if a separate system)
Cylinder coolant inlet pressure or flow*++	Low	Slow-down (automatic on trunk piston engines)
Cylinder coolant outlet temperature*++	1st stage High++	Per cylinder (if a separate system) Slow-down (automatic on trunk piston engines)++
Engine cooling water system – oil content	High	Required for crosshead engines where engine cooling water used in oil/water heat exchangers
Sea-water cooling pressure	Low	-
Fuel valve coolant pressure	Low	If a separate system
Fuel valve coolant temperature	High	If a separate system
Fuel oil pressure from booster pump	Low	-
Fuel oil temperature or viscosity*	High and Low	Heavy oil only
Fuel oil high pressure piping*	Leakage	*See Pt 10, Ch 1, 7.5 Unattended machinery 7.5.5*
Common rail fuel oil pressure	Low	-
Common rail servo oil pressure	Low	-
Charge air cooler outlet temperature	High	Trunk piston engines
Scavenge air temperature (fire)	High	Per cylinder, (2 stroke engines) Slow-down
Uptake temperature	High	To monitor for soot fires. *See* Notes 8 and 9
Scavenge air receiver water level	High	-

Exhaust gas temperature*	High	Per cylinder Slow-down (automatic on trunk piston engines), *see* Note 5
Exhaust gas temperature deviation from average*	High	Per cylinder, *see* Note 5
Turbocharger speed	High	Category B and C turbochargers, *see* Notes 11 and 12
Turbocharger exhaust gas inlet temperature	High	Category B and C turbochargers *see* Notes 6 and 12
Turbocharger lubricating oil inlet pressure	Low	Only for forced lubrication systems on category B and C turbochargers, *see* Notes 7, 10 and 12
Turbocharger lubricating oil outlet temperature	High	Category C turbochargers, if not a forced system, oil temperature near each bearing, *see* Notes, 7 and 12
Starting air pressure*	Low	Before engine manoeuvring valve
Control air pressure	Low	-
Direction of rotation	Wrong way	Reversible engines, *see also Pt 10, Ch 1, 7.6 Engines for propulsion purposes 7.6.7*
Automatic start of engine	Failure	*See Pt 10, Ch 1, 7.6 Engines for propulsion purposes 7.6.7*
Electrical starting battery charge level	Low	-

Feed water or water/thermal fluid forced circulation flow (if fitted)	Low	*See Rules and Regulations for the Classification of Ships, July 2021 Pt 5, Ch 14, 6.2 Feed and circulation pumps 6.2.7* and Note 8

Note 1. Where 'per cylinder' appears in this Table, suitable alarms may be situated on manifold outlets for trunk piston engines.

Note 2. For engines and gearing of 1500 kW or less, only the items marked * are required.

Note 3. For service craft with engines of 500 kW or less, only items marked ++ are required.

Note 4. Where the outlet temperature for each bearing cannot be measured due to the design, details of alternative proposals in accordance with the turbocharger manufacturer's instructions may be submitted for consideration.

Note 5. For trunk piston engine power <500 kW/cylinder, a common sensor for exhaust gas manifold temperature may be fitted.

Note 6. Alarm and indication of the exhaust gas temperature at turbocharger inlet may be waived if alarm and indication for individual exhaust gas temperature is provided for each cylinder and the alarm level is set to a value specified by the turbocharger manufacturer. For Category B turbochargers, the exhaust gas temperature may be alternatively monitored at the turbocharger outlet provided that the correlation between inlet and outlet temperatures is established and verified and the alarm level is set to a correspondingly safe level for the turbine.

Note 7. Where the outlet temperature for each bearing cannot be measured due to the design, details of alternative proposals in accordance with the turbocharger manufacturer's instructions may be submitted for consideration.

Note 8. Alarm only required when an exhaust gas economiser/boiler/thermal oil heater is fitted.

Note 9. Alternatively, details of an appropriate fire detection system are to be submitted for consideration.

Note 10. Separate sensors are to be provided if the lubrication oil system of the turbocharger is not integrated with the lubrication oil system of the engine or if it is separated by a throttle or pressure reduction valve from the engine lubrication oil system. Where the turbocharger is provided with a self-contained lubricating oil system integrated with the turbocharger, lubricating oil inlet pressure need not be monitored.

Note 11. Where multiple turbochargers are activated sequentially, speed monitoring is not required for the turbocharger(s) being activated last in the sequence, provided that all turbochargers share the same intake air filter and they are not fitted with waste gates.

Note 12. *See Pt 10, Ch 1, 12.1 General 12.1.2* for details of turbocharger categorisations.

Table 1.7.2 Engines for propulsion purposes: Automatic shutdowns

Item	Alarm	Note
Lubricating oil inlet pressure*	2nd stage low	Automatic shutdown of engines, *see Pt 10, Ch 1, 7.5 Unattended machinery 7.5.4*
Activation of oil mist detection arrangements (or activation of the temperature monitoring systems or equivalent devices of: - the engine main and crank bearing oil outlet; or - the engine main and crank bearing)	High	For trunk piston engines, automatic shutdown. For crosshead engines, *see Table 1.7.1 Engines for propulsion purposes: alarms and safeguards slow-downs . See also Pt 10, Ch 1, 7.1 General 7.1.2*
Cylinder coolant outlet temperature	2nd stage high	Automatic shutdown of trunk piston engines, *see Pt 10, Ch 1, 7.5 Unattended machinery 7.5.4*

Overspeed*	High	Automatic shutdown of engine, *see also Pt 10, Ch 1, 7.4 Overspeed protective devices* protection devices. Details of alternative proposals in accordance with the manufacturer's instructions may be submitted for consideration
NOTE For engines and gearing of 1500 kW or less, only the items marked * are required.		

7.6.2 Alarms are to operate, for the fault conditions shown in *Table 1.7.1 Engines for propulsion purposes: alarms and safeguards slow-downs* . Where applicable,indication is to be given at the relevant control stations that the speed or power of the main propulsion engine(s) is to be manually reduced or has been reduced automatically.

7.6.3 Alarms are to operate, and automatic shutdown of machinery is to occur for the fault conditions shown in *Table 1.7.2 Engines for propulsion purposes: Automatic shutdowns*

7.6.4 The following engine services are to be fitted with automatic temperature controls so as to maintain steady state conditions throughout the normal operating range of the propulsion engine(s):

(a) Lubricating oil supply.
(b) Fuel oil supply, *see also Pt 10, Ch 1, 7.6 Engines for propulsion purposes 7.6.5*
(c) Piston coolant supply, where applicable.
(d) Cylinder coolant supply, where applicable.
(e) Fuel valve coolant supply, where applicable.

7.6.5 The fuel oil supply may be fitted with an automatic control for viscosity instead of the temperature control required by *Pt 10, Ch 1, 7.6 Engines for propulsion purposes 7.6.4*.

7.6.6 Indication of the starting air pressure is to be provided at each control station from which it is possible to start the main propulsion engine(s).

7.6.7 The number of automatic consecutive attempts which fail to produce a start is to be limited to three. For reversible engines which are started and stopped for manoeuvring purposes, means are to be provided to maintain sufficient starting air in the air receivers. For electric starting, *see Pt 10, Ch 1, 9.3 Electric starting*.

7.6.8 Prolonged running in a barred speed range is to be prevented automatically or, alternatively, an indication of restricted speed ranges is to be provided at each control station.

7.7 Auxiliary engines

7.7.1 Alarms and safeguards are indicated in *Table 1.7.3 Auxiliary engine alarms and safeguards*.

Table 1.7.3 Auxiliary engine alarms and safeguards

Item	Alarm	Note
Lubricating oil inlet temperature	High	-
Lubricating oil inlet pressure	1st stage Low	-
Lubricating oil inlet pressure	2nd stage Low	Automatic shutdown of engine, *see Pt 10, Ch 1, 7.5 Unattended machinery 7.5.4*
Activation of oil mist detection arrangements (or activation of the temperature monitoring systems or equivalent devices of: - the engine main and crank bearing oil outlet; or - the engine main and crank bearing)	High	Automatic shutdown of engine, *see also Pt 10, Ch 1, 7.1 General 7.1.2*
Fuel oil high pressure piping	Leakeage	*See Pt 10, Ch 1, 7.5 Unattended machinery 7.5.5*

Coolant outlet temperature (for engines >220 kW)	1st stage High	-
	2nd stage High	Automatic shutdown of engine, *see Pt 10, Ch 1, 7.5 Unattended machinery 7.5.4*
Coolant pressure or flow	Low	-
Overspeed	High	Automatic shutdown of engine, *see also Pt 10, Ch 1, 7.4 Overspeed protective devices*. Details of alternative proposals in accordance with the manufacturer's instructions may be submitted for consideration
Starting air pressure	Low	-
Electric starting battery charge level	Low	-
Fuel oil inlet temperature or viscosity	High and low	Heavy oil only
Common rail servo oil pressure	Low	-
Common rail fuel oil pressure	Low	-
Exhaust gas temperature (for engines >500 kW/cylinder)	High	Per cylinder
Feed water or water/thermal fluid forced circulation flow (if fitted)	Low	*See Pt 5, Ch 14, 6.2 Feed and circulation pumps 6.2.7* of the *Rules and Regulations for the Classification of Ships, July 2021* and Note 3
Uptake temperature	High	To monitor for soot fires. See Notes 3 and 4
Turbocharger speed	High	Category B and C turbochargers, *see* Notes 7and 9
Turbocharger exhaust gas inlet temperature	High	Category B and C turbochargers, *see* Notes 8 and 9
Turbocharger lubricating oil outlet temperature	High	Category C turbochargers, if not a forced system, oil temperature near each bearing, *see* Notes 6 and 9
Turbocharger lubrication oil inlet pressure	Low	Only for forced lubrication systems on category B and C turbochargers, *see* Notes 5, 6 and 9

Note 1. For emergency diesel engines, including engines used for the emergency source of electrical power required by SOLAS.

Note 2. The arrangements are to comply with the requirements of the National Authority concerned.

Note 3. Alarm only required when an exhaust gas economiser/boiler/thermal oil heater is fitted.

Note 4. Alternatively, details of an appropriate fire detection system are to be submitted for consideration.

Note 5. Separate sensors are to be provided if the lubrication oil system of the turbocharger is not integrated with the lubrication oil system of the engine or if it is separated by a throttle or pressure-reduction valve from the engine lubrication oil system.

Note 6. Where outlet temperature from each bearing cannot be monitored due to the engine/turbocharger design alternative arrangements may be accepted. Continuous monitoring of inlet pressure and inlet temperature in combination with specific intervals for bearing inspection in accordance with the turbocharger manufacturer's instructions may be accepted as an alternative.

Note 7. Where multiple turbochargers are activated sequentially, speed monitoring is not required for the turbocharger(s) being activated last in the sequence, provided that all turbochargers share the same intake air filter and they are not fitted with waste gates.

Note 8. Alarm and indication of the exhaust gas temperature at the turbocharger inlet is not required if alarm and indication for individual exhaust gas temperature are provided for each cylinder and the alarm level is set to a value specified by the turbocharger manufacturer. For Category B turbochargers, the exhaust gas temperature may be alternatively monitored at the turbocharger outlet provided that correlation between inlet and outlet temperatures is established and verified and the alarm level is set to a correspondingly safe level for the turbine.

Note 9. *See Pt 10, Ch 1, 12.1 General 12.1.2* for details of turbocharger categorisations.

7.7.2 For engines operating on heavy fuel oil, automatic temperature or viscosity controls are to be provided.

7.8 Emergency engines

7.8.1 Alarms and safeguards are indicated in *Table 1.7.4 Emergency engines: Alarms and safeguards*.

Table 1.7.4 Emergency engines: Alarms and safeguards

Item	Alarm for engine power < 220 kW	Alarm for engine power ≥ 220 kW	Note
Fuel oil leakage from pressure pipes	Leakage	Leakage	*See Pt 10, Ch 1, 7.5 Unattended machinery 7.5.5*
Lubricating oil temperature	—	High	—
Lubricating oil pressure	Low	Low	—
Activation of oil mist detection arrangements (or activation of the temperature monitoring systems or equivalent devices of: - the engine main and crank bearing oil outlet; or - the engine main and crank bearing)	—	High	*See* Note
Coolant pressure or flow	—	Low	—
Coolant Temperature (can be air)	High	High	—
Overspeed	—	High	Automatic shutdown
Note For engines having a power of more than 2250 kW or a cylinder bore of more than 300 mm.			

7.8.2 The safety and alarm systems are to be designed to 'fail safe'. The characteristics of the 'fail safe' operation are to be evaluated on the basis not only of the system and its associated machinery, but also the complete installation, as well as the craft.

7.8.3 Regardless of the engine output, if shutdowns additional to those specified in *Table 1.7.4 Emergency engines: Alarms and safeguards* are provided except for the overspeed shutdown, they are to be automatically overridden when the engine is in automatic or remote control mode during navigation.

7.8.4 Grouped alarms of at least those items listed in *Table 1.7.4 Emergency engines: Alarms and safeguards* are to be arranged on the bridge.

7.8.5 In addition to the fuel oil control from outside the space, a local means of engine shutdown is to be provided.

7.8.6 Local indications of at least those items listed in *Table 1.7.4 Emergency engines: Alarms and safeguards* are to be provided within the same space as the diesel engines and are to remain operational in the event of failure of the alarm and safety systems.

7.9 Engine stopping

7.9.1 At least two independent means of stopping the engines quickly from the control station under any conditions are to be available.

■ Section 8
Piping

8.1 Fuel oil and hydraulic and high pressure oil systems

8.1.1 Fuel oil and hydraulic oil piping system arrangements are to comply with *Pt 15, Ch 1 Piping Design Requirements* and *Pt 15, Ch 3 Machinery Piping Systems* as applicable.

8.1.2 Engine fuel system components are to be designed to accommodate the maximum peak pressures experienced in service. Where fuel injection pumps are fitted, particular attention is to be given to the fuel injection pump supply and spill line piping which may be subject to high-pressure pulses from the pump. Connections on such piping systems should be chosen to minimise the risk of pressurised fuel oil leaks. Fatigue analysis may be considered necessary to establish the suitability of the piping system components for the pressures and fluctuating stresses that the pipe system may be subject to in normal service.

8.1.3 On engines used for propulsion, where fuel oil and hydraulic oil pressure pumps are fitted, and these are essential for engine operation, not less than two fuel oil and two hydraulic oil pressure pumps are to be provided and arranged such that failure of one pump does not render the other pump(s) inoperative. Each fuel oil pump and hydraulic oil pump is to be capable of supplying the quantity of oil for engine operation at its maximum continuous rating and arranged ready for immediate use.

8.1.4 External high-pressure fuel delivery piping between the fuel injection pump or high-pressure fuel pumps and fuel injectors is to be protected with a jacketed piping system capable of containing leakage and/or spray of flammable fluid from a high-pressure line failure. The jacketed piping arrangements are to be approved, *see Table 1.1.1 Plans and particulars to be submitted*. The protection of high-pressure fuel pipes on common rail fuel systems will be specially considered.

8.1.5 The protection required by *Pt 10, Ch 1, 8.1 Fuel oil and hydraulic and high pressure oil systems 8.1.10* is to prevent fuel oil or fuel oil mist from reaching a source of ignition on the engine or its surroundings. Suitable drainage arrangements are to be made for draining any fuel oil leakage to one or more collector tanks fitted in a safe position. These tanks are to be separate from any tank used to collect other oils such as lube oil or hydraulic oil to prevent cross contamination. An alarm is to be provided to indicate that leakage is taking place. The collector tank arrangement is to be approved.

8.1.6 Hydraulic oil pressure piping between the high-pressure hydraulic pumps and hydraulic actuators is to be protected with a jacketed piping system or suitable enclosure capable of containing hydraulic oil leakage from a high-pressure pipe failure. Where flammable oils are used in high-pressure systems to operate exhaust valves, the oil pipe lines between the high-pressure oil pump and actuating oil pistons are to be protected with a jacketed piping system capable of preventing oil spray from a high-pressure line failure.

8.1.7 All lubricating and hydraulic oil pipes, and fuel oil pipes that are not jacketed or enclosed, are to be suitably installed and screened to avoid oil spray or leakage onto hot surfaces, *see also Pt 15, Ch 3, 4.11 Precautions against fire 4.11.1* as applicable,

8.1.8 Where flammable oils are used in high-pressure actuating systems, a fatigue analysis is to be carried out in accordance with a suitable standard and all anticipated pressure, pulsation and vibration loads are to be considered. The analysis is to demonstrate that the design and arrangements are such that the likelihood of failure is as low as reasonably practicable. The analysis is to identify all assumptions made and standards to be applied during manufacture and testing. Any potential weak points which may develop due to incorrect construction or assembly are also to be identified.

8.1.9 Accumulators and associated high pressure piping are to be designed, manufactured and tested in accordance with a standard applicable to the maximum pressure and temperature rating of the system.

8.1.10 For high pressure oil containing and mechanical power transmission systems, the quality plan for sourcing, design, installation and testing of components is to address the following issues (*Table 1.1.1 Plans and particulars to be submitted*, Note 11:

(a) Design and manufacturing standard(s) applied.
(b) Materials used for construction of key components and their sources.
(c) Details of the quality control system applied during manufacture and testing.
(d) Details of type approval, type testing or approved type status assigned to the machinery or equipment.
(e) Details of installation and testing recommendations for the machinery or equipment.

8.2 Additional requirements for fuel oil, hydraulic and high pressure oil systems for special service craft

8.2.1 Small craft not required to comply with the *HSC Code - International Code of Safety for High Speed Craft, 1994 – Resolution MSC.36(63)* are to be capable of maintaining adequate manoeuvring capability.

8.2.2 Where multi-engine installations on board special service craft required to comply with the *SOLAS - International Convention for the Safety of Life at Sea* and yachts that are of 500 gt or more are supplied from the same fuel source, means of isolating the fuel supply and spill piping to individual engines is to be provided. These means of isolation are not to affect the operation of the other engines and are to be operable from a position not rendered inaccessible by a fire on any of the engines.

8.2.3 Where fuel treatments, additives or emulsified fuel are used as a means of abating exhaust emissions, engines and fuel systems are to be compatible with such additives, treatments and emulsified fuel.

8.3 Exhaust systems

8.3.1 Where the surface temperature of the exhaust pipes and silencer may exceed 220°C, they are to be water cooled or efficiently lagged to minimise the risk of fire and to prevent damage by heat. Where lagging covering the exhaust piping system including flanges is oil-absorbing or may permit penetration of oil, the lagging is to be encased in sheet metal or equivalent. In locations where the Surveyor is satisfied that oil impingement could not occur, the lagging need not be encased.

8.3.2 Where the exhausts of two or more engines are led to a common silencer or exhaust gas-heated boiler or economiser, an isolating device is to be provided in each exhaust pipe.

8.3.3 For alternatively fired furnaces of boilers using exhaust gases and fuel oil, the exhaust gas inlet pipe is to be provided with an isolating device and interlocking arrangements whereby fuel oil can only be supplied to the burners when the isolating device is closed to the boiler.

8.3.4 In two-stroke main engines, fitted with exhaust gas turbo-blowers which operate on the impulse system, provision is to be made to prevent broken piston rings entering the turbine casing and causing damage to blades and nozzle rings.

8.3.5 Where the exhaust is led overboard near the waterline, the exhaust system shall be so designed as to prevent water from entering the engine exhaust manifold through wave or wake action, both when the engine is in operation or shut down. The system shall also be designed to prevent ingress of water at the angles of inclination as shown in *Pt 9, Ch 1, 4.2 Inclinations of the craft*.

8.3.6 Where the exhaust is cooled by water spray, the exhaust pipes are to be self-draining overboard. Suitable measures shall be taken to prevent inadvertent closure of drain valves where this may lead to sprayed water entering the engine. Means shall be provided to prevent water from flowing back into the engine when the engine is stopped.

8.3.7 Exhaust systems having components sensitive to heat shall be fitted with a high temperature alarm after water injection. This alarm shall be integrated into the craft's alarm system.

8.3.8 Exhaust pipes penetrating the shell below the bulkhead deck shall be provided with a shipside valve or other approved positive means of closure at the shell to prevent back-flooding into the hull through a damaged exhaust system.

8.3.9 The exhaust system shall be designed such that the exhaust back-pressure is within the allowable limits stated by the engine manufacturer under all expected operating conditions.

8.4 Additional exhaust system requirements

8.4.1 Engine inlets are to be arranged to provide sufficient air to the engines whilst minimising the ingestion of harmful particles.

8.4.2 The arrangement of the exhaust system is to be such as to prevent exhaust gases being drawn into the manned spaces, air conditioning systems and air intakes. They should not discharge into air cushion intakes.

8.4.3 For small service craft not required to comply with the HSC Code, where the lowest point of the exhaust outlet is well above the waterline, alternative arrangements to those specified in *Pt 10, Ch 1, 8.3 Exhaust systems 8.3.8* may be submitted for consideration. Details of the alternative arrangements are to be included in the documentation required by *Pt 10, Ch 1, 1.4 Submission requirements* and are to demonstrate:

(a) equivalence to *Pt 10, Ch 1, 8.3 Exhaust systems 8.3.8* is achieved; and
(b) compliance with the applicable statutory requirements of the National Authority of the country in which the craft is to be registered.

8.4.4 Plastic pipes intended for exhaust systems are to comply with the relevant requirements in *Pt 15, Ch 1, 8 Plastic pipes*. *See Pt 15, Ch 1, 15.5 Plastic pipes* for small craft not required to comply with the HSC Code.

8.5 Starting air pipe systems and safety fittings

8.5.1 In designing the compressed air installation, care is to be taken that the compressor air inlets will be located in an atmosphere reasonably free from oil vapour or, alternatively, an air duct from outside the machinery space is to be led to the compressors.

8.5.2 The air discharge pipe from the compressors is to be led direct to the starting air receivers. Provision is to be made for intercepting and draining oil and water in the air discharge, for which purpose a separator or filter is to be fitted in the discharge pipe between compressors and receivers.

8.5.3 The starting air pipe system from receivers to main and auxiliary engines is to be entirely separate from the compressor discharge pipe system. Stop valves on the receivers are to permit slow opening to avoid sudden pressure rises in the piping system. Valve chests and fittings in the piping system are to be of ductile material.

8.5.4 Drain valves for removing accumulations of oil and water are to be fitted on compressors, separators, filters and receivers. In the case of any low-level pipelines, drain valves are to be fitted to suitably located drain pots or separators.

8.5.5 The starting air piping system is to be protected against the effects of explosions by providing an isolating non-return valve or equivalent at the starting air supply to each engine.

8.5.6 In direct reversing engines bursting discs or flame arresters are to be fitted at the starting valves on each cylinder; in non-reversing and auxiliary engines at least one such device is to be fitted at the supply inlet to the starting air manifold on each engine. The fitting of bursting discs or flame arresters may be waived in engines where the cylinder bore does not exceed 230 mm.

8.5.7 Alternative safety arrangements may be submitted for consideration.

8.6 Emissions abatement systems

8.6.1 Where it is proposed to install wet scrubbing emissions abatement equipment requiring wash water to be sprayed into a reactor tower along with wash water tanks and circulation systems, effluent retention tanks and conditioning equipment, such designs are to meet the requirements of *Pt 5, Ch 24 Emissions Abatement Plant for Combustion Machinery* of the *Rules and Regulations for the Classification of Ships, July 2021*.

8.6.2 Where fuel treatments, additives or emulsified fuel are used as a means of abating exhaust emissions, engines and fuel systems are to be compatible with such additives, treatments and emulsified fuel

8.6.3 Where chemicals or substances are injected into the exhaust gas flow before engine turbo-charger(s) or emissions abatement equipment, this is not to present a risk of damage, chemical attack or performance degradation to the turbo-charger(s) or emissions abatement equipment.

8.6.4 Where emissions abatement equipment is installed as part of the exhaust system, the exhaust system is to be capable of safely transmitting the minimum and maximum exhaust gas flows also with the emissions abatement equipment out of operation.

8.6.5 Where emissions abatement equipment is to be installed as part of the exhaust system, the resulting exhaust gas system back pressure is to remain within the allowable limits stated by engine manufacturer, and a means of measuring differential pressure across the emissions abatement equipment is to be provided.

■ *Section 9*
Starting arrangements

9.1 Dead ship condition starting arrangements

9.1.1 Means are to be provided to ensure that machinery can be brought into operation from the dead ship condition without external aid.

9.1.2 Dead ship condition for the purpose of *Pt 10, Ch 1, 9.1 Dead ship condition starting arrangements 9.1.1* is to be understood to mean a condition under which the main propulsion plant and auxiliaries are not in operation. In restoring propulsion,

no stored energy for starting and operating the propulsion plant is assumed to be available. Additionally, neither the main source of electrical power nor other essential auxiliaries is assumed to be available for starting and operating the propulsion plant.

9.1.3 Where the emergency source of power is an emergency generator which fully complies with the requirements of *Pt 16, Ch 2 Electrical Engineering*, this generator may be used for restoring operation of the main propulsion plant, boilers and auxiliaries where any power supplies necessary for engine operation are also protected to a similar level as the starting arrangements.

9.1.4 Where there is no emergency generator installed or an emergency generator does not comply with *Pt 16, Ch 2 Electrical Engineering*, the arrangements for bringing main and auxiliary machinery into operation are to be such that the initial charge of starting air or initial electrical power and any power supplies for engine operation can be developed on board the craft without external aid. If, for this purpose, an emergency air compressor or an electric generator is required, these units are to be powered by a hand-starting oil engine or a hand-operated compressor. The arrangements for bringing main and auxiliary machinery into operation are to have capacity such that the starting energy and any power supplies for engine operation are available within 30 minutes of a dead ship condition.

9.1.5 For cargo vessels of less than 500 gross tons and which are not required to comply with the *SOLAS - International Convention for the Safety of Life at Sea*, 1974, as amended (SOLAS 74), alternative arrangements to those specified in *Pt 10, Ch 1, 9.1 Dead ship condition starting arrangements 9.1.3* or *Pt 10, Ch 1, 9.1 Dead ship condition starting arrangements 9.1.4* may be proposed for consideration. Details of the alternative arrangements are to be included in the plans and details required by *Table 1.1.1 Plans and particulars to be submitted* and are to demonstrate that the arrangements provide for starting from the dead ship condition and are in accordance with any applicable statutory requirements of the National Authority of the country in which the vessel is to be registered.

9.1.6 Reciprocating air compressors intended for starting main engines and auxiliary engines providing essential services are to comply with the requirements of *Pt 10, Ch 1, 4 Electronically controlled engines*.

9.2 Air receiver capacity

9.2.1 Where the main engine is arranged for air starting the total air receiver capacity is to be sufficient to provide without replenishment, not less than 12 consecutive starts of the main engine, alternating between ahead and astern if of the reversible type and not less than six consecutive starts if of the non-reversible type. At least two air receivers of approximately equal capacity are to be provided. For scantlings and fittings of air receivers, *see Pt 15, Ch 4 Pressure Plant*.

9.2.2 For multi-engine installations, the number of starts required for each engine are to be as follows:

(a) Two engines through common reduction gearing: 6 starts per engine for fixed pitch propeller/propellers; 3 starts per engine for controllable pitch propeller/propellers.
(b) For all other types of multi-engine installations three consecutive starts per engine are required.

9.2.3 No engine is to have fewer than 3 starts for any arrangement. For electric propulsion arrangements, a minimum of 3 starts per engine with a minimum capacity of 12 starts of the largest start air consumption engine in total are required.

9.2.4 Each air receiver is to be fitted with a drain arrangement at its lowest part, permitting oil and water to be blown out.

9.2.5 Each receiver which can be isolated from a relief valve is to be provided with a suitable fusible plug to discharge the contents in case of fire. The melting point of the fusible plug is to be approximately 150ºC, *see also Pt 15, Ch 4, 9.2 Receivers containing pressurised gases*.

9.2.6 Receivers used for the storage of air for the control of remotely operated valves are to be fitted with relief valves and not fusible plugs.

9.3 Electric starting

9.3.1 Where main engines are fitted with electric starters, two batteries are to be fitted. Each battery is to be capable of starting the engines when cold and the combined capacity is to be sufficient without recharging to provide the number of starts of the main engines as required by *Pt 10, Ch 1, 9.2 Air receiver capacity* . In other respects batteries are to comply with the requirements of *Pt 16, Ch 2, 12 Batteries*.

9.3.2 Electric starting arrangements for auxiliary engines are to have two separate batteries or be supplied by separate circuits from the main engine batteries when such are provided. Where one of the auxiliary engines only is fitted with an electric starter one battery will be acceptable.

9.3.3 The combined capacity of the batteries for starting the auxiliary engines is to be sufficient for at least three starts for each engine.

9.3.4 Engine starting batteries are to be used only for the purposes of starting the engines and for the engines' own control, alarm, monitoring and safety arrangements. Means are to be provided to ensure that the stored energy in the batteries is maintained at a level required to start the engines as defined in *Pt 10, Ch 1, 9.3 Electric starting 9.3.1* and *Pt 10, Ch 1, 9.3 Electric starting 9.3.3*.

9.3.5 Where engines are fitted with electric starting batteries, an alarm is to be provided for low charge battery level.

9.4 Additional requirements for electric starting for non-SOLAS cargo vessels

9.4.1 For cargo vessels of less than 500 gross tons which are not required to comply with the *SOLAS - International Convention for the Safety of Life at Sea*, the emergency source of electrical power may be used as one of the sources of energy required by *Pt 10, Ch 1, 9.3 Electric starting 9.3.1* or *Pt 10, Ch 1, 9.3 Electric starting 9.3.2* for electric starting. Where the emergency source of electrical power is an accumulator battery and it is to be used for electric starting, it is to have the additional capacity required to ensure emergency supplies are not compromised and is to be adequately protected and suitably located for use in an emergency.

9.5 Starting of the emergency source of power

9.5.1 Emergency generators are to be capable of being readily started in their cold conditions down to a temperature of 10ºC. If this is impracticable, or if lower temperatures are likely to be encountered, consideration is to be given to the provision and maintenance of heating arrangements, so that ready starting will be assured.

9.5.2 Each emergency generator that is arranged to be automatically started is to be equipped with an approved starting system having two independent sources of stored energy, each of which is sufficient for at least three consecutive starts. When hand (manual) starting is demonstrated to be effective, only one source of stored energy need be provided. However, this source of stored energy is to be protected against depletion below the level required for starting.

9.5.3 Provision is to be made to maintain continuously the stored energy at all times, and for this purpose:

(a) Electrical and hydraulic starting systems are to be maintained from the emergency switchboard.
(b) Compressed air starting systems may be maintained by the main or auxiliary compressed air receivers, through a suitable non-return valve, or by an emergency air compressor energised by the emergency switchboard.
(c) All these starting, charging and energy storing devices are to be located in the emergency generator room. These devices are not to be used for any purpose other than the operation of the emergency generator.

9.5.4 When automatic starting is not required by the Rules and where it can be demonstrated as being effective, hand (manual) starting is permissible, such as manual cranking, inertial starters, manual hydraulic accumulators, powder charge cartridges.

9.5.5 When hand (manual) starting is not practicable, the provisions of *Pt 10, Ch 1, 9.5 Starting of the emergency source of power 9.5.2* and *Pt 10, Ch 1, 9.5 Starting of the emergency source of power 9.5.3* are to be complied with except that starting may be manually initiated.

9.5.6 Electric starting arrangements are to also satisfy *Pt 10, Ch 1, 9.3 Electric starting 9.3.2* to *Pt 10, Ch 1, 9.3 Electric starting 9.3.5*.

9.6 Engine control, alarm monitoring and safety system power supplies

9.6.1 Power supplies are to be arranged so that power for electrically powered control, alarm monitoring and safety systems required for engine starting and operation will remain available in the event of a failure. Power is to remain available to permit starting attempts for the number of starts specified by this Section for each source of stored energy.

9.6.2 Where adequate battery and charging capacity exists, an engine starting battery may be used as one source of electrical power required by *Pt 10, Ch 1, 9.6 Engine control, alarm monitoring and safety system power supplies 9.6.1* .

9.6.3 An alarm is to be activated in the event of failure of a power supply and, where applicable, low battery charge level. Manual power supply changeover facilities are permitted.

Section 10
Safety arrangements

10.1 Cylinder relief valves

10.1.1 Scavenge spaces in open connection with cylinders are to be provided with explosion relief valves.

10.1.2 Crankcases are to be provided with lightweight spring-loaded valves or other quick-acting and self-closing devices to relieve the crankcases of pressure in the event of an internal explosion and to prevent any inrush of air thereafter. The valves are to be designed and constructed to open quickly and be fully open at a pressure not greater than 0,2 bar.

10.1.3 The valve lids are to be made of ductile material capable of withstanding the shock of contact with stoppers at the full open position.

10.1.4 Each valve is to be fitted with a flame arrester that permits flow for crankcase pressure relief and prevents the passage of flame following a crankcase explosion. The valves are to be type tested in a configuration that represents the installation arrangements that will be used on an engine and in accordance with *Pt 10, Ch 1, 14.3 Crankcase explosion relief valves*. The valves are to be positioned on engines to minimise the possibility of danger and damage arising from emission of the crankcase atmosphere. Where shielding from the emissions is fitted to a valve, the valve is to be type tested to demonstrate that the shielding does not adversely affect the operational effectiveness of the valve.

10.1.5 The valves are to be provided with a copy of the manufacturer's installation and maintenance manual for the size and type of valve being supplied for installation on a particular engine. The manual is to contain the following information:

- Description of valve with details of function and design limits.
- Copy of type test certification.
- Installation instructions.
- Maintenance and in-service instructions to include testing and renewal of any sealing arrangements.
- Actions required after a crankcase explosion.

10.1.6 A copy of the installation and maintenance manual required by *Pt 10, Ch 1, 10.1 Cylinder relief valves 10.1.5* is to be provided on board the ship.

10.1.7 Plans showing details and arrangements of the relief valves are to be submitted for approval, *see Pt 10, Ch 1, 1.4 Submission requirements 1.4.3*.

10.1.8 The valves are to be provided with suitable markings that include the following information:

- Name and address of manufacturer.
- Designation and size.
- Month/Year of manufacture.
- Approved installation orientation.

10.2 Number of relief valves

10.2.1 Internal combustion engines having a cylinder bore of 200 mm and above or a crankcase volume of 0,6 m^3 and above shall be provided with crankcase explosion relief valves.

10.2.2 In engines having cylinders exceeding 200 mm but not exceeding 250 mm bore, at least two relief valves are to be fitted; each valve is to be located at or near the ends of the crankcase. Where the engine has more than eight crankthrows an additional valve is to be fitted near the centre of the engine.

10.2.3 In engines having cylinders exceeding 250 mm but not exceeding 300 mm bore, at least one relief valve is to be fitted in way of each alternate crankthrow with a minimum of two valves. For engines having 3, 5, 7, 9, etc. crankthrows, the number of relief valves is not to be less than 2, 3, 4, 5, etc. respectively.

10.2.4 In engines having cylinders exceeding 300 mm bore at least one valve is to be fitted in way of each main crankthrow.

10.2.5 Additional relief valves are to be fitted for separate spaces on the crankcase, such as gear or chaincases for camshaft or similar drives, when the gross volume of such spaces exceeds 0,6 m^3.

10.3 Size of relief valves

10.3.1 The combined free area of the crankcase relief valves fitted on an engine is to be not less than 115 cm^2/m^3 based on the volume of the crankcase.

10.3.2 The free area of each relief valve is to be not less than 45 cm^2.

10.3.3 The free area of the relief valve is the minimum flow area at any section through the valve when the valve is fully open.

10.3.4 In determining the volume of the crankcase for the purpose of calculating the combined free area of the crankcase relief valves, the volume of the stationary parts within the crankcase may be deducted from the total internal volume of the crankcase.

10.4 Vent pipes

10.4.1 Through ventilation, and any arrangement which could produce a flow of external air within the crankcase, is in principle not permitted except for trunk piston type dual fuel engines where crankcase ventilation is to be provided. Where crankcase vent or breather pipes are fitted, they are to be made as small as practicable and/or as long as possible to minimise the inrush of air after an explosion. Vent or breather pipes from crankcases of main engines are to be led to a safe position on deck or other approved position.

10.4.2 If provision is made for the extraction of gases from within the crankcase, e.g. for oil mist detection purposes, the vacuum within the crankcase is not to exceed 25 mm of water.

10.4.3 Lubricating oil drain pipes from engine sump to drain tank are to be submerged at their outlet ends. Where two or more engines are installed, vent pipes, if fitted, and lubrication oil drain pipes are to be independent to avoid intercommunication between crankcases.

10.5 Warning notice

10.5.1 A warning notice is to be fitted in a prominent position, preferably on a crankcase door on each side of the engine, or alternatively at the engine room control station. This warning notice is to specify that whenever overheating is suspected in the crankcase, the crankcase doors or sight holes are not to be opened until a reasonable time has elapsed after stopping the engine, sufficient to permit adequate cooling within the crankcase.

10.6 Crankcase access and lighting

10.6.1 Where access to crankcase spaces is necessary for inspection purposes, suitably positioned rungs or equivalent arrangements are to be provided as considered appropriate.

10.6.2 When interior lighting is provided it is to be flameproof in relation to the interior (details of which are to be submitted for approval). No wiring is to be fitted inside the crankcase.

10.7 Fire-extinguishing system for scavenge manifolds

10.7.1 Crosshead type engine scavenge spaces in open connection with cylinders are to be provided with approved fixed or portable fire-extinguishing arrangements, which are to be independent of the fire-extinguishing system of the engine room.

10.8 Oil mist detection

10.8.1 Oil mist detection, engine bearing temperature monitors are to be provided:

(a) When arrangements are fitted to override the automatic shutdown for excessive reduction of the lubricating oil supply pressure.
(b) For engines of 2,250 kW and above or having cylinders of more than 300 mm bore.

10.8.2 Where crankcase oil mist detection arrangements are fitted, they are to be of a type approved by LR, tested in accordance with *Pt 10, Ch 1, 14.4 Crankcase oil mist detection system 14.4.4* and comply with *Pt 10, Ch 1, 10.8 Oil mist detection 10.8.2* and *Pt 10, Ch 1, 10.8 Oil mist detection 10.8.16*.

10.8.3 The oil mist detection system and arrangements are to be installed in accordance with the engine designer's and oil mist detection equipment manufacturer's instructions/recommendations. The following particulars are to be included in the instructions:

(a) A Schematic layout of the engine oil mist detection and alarm system showing locations of engine crankcase sample points and cabling/piping arrangements together with pipe dimensions to the detector.

(b) Evidence of study to justify the selected locations of sample points and sample extraction rate (if applicable) in consideration of the crankcase arrangements and geometry and the predicted crankcase atmosphere where oil mist can accumulate.
(c) The manufacturer's maintenance and test manual.
(d) Information relating to type or in-service testing of the engine with engine protection system test arrangements having approved types of oil mist detection equipment.

10.8.4 A copy of the oil mist detection equipment maintenance and test manual required by *Pt 10, Ch 1, 10.8 Oil mist detection 10.8.3* is to be provided on board the craft.

10.8.5 Oil mist detection and alarm information is to be capable of being read from a safe location away from the engine.

10.8.6 In the case of multi engine installations, each engine is to be provided with individual, dedicated oil mist detection arrangements and alarm(s).

10.8.7 Oil mist detection and alarm systems are to be capable of being tested on the test bed and on board when the engine is at a standstill and when the engine is running at normal operating conditions in accordance with test procedures that are acceptable to LR.

10.8.8 Alarms and safeguards for the oil mist detection system are to be in accordance with *Pt 16, Ch 1 Control Engineering Systems* as applicable.

10.8.9 The oil mist detection arrangements are to provide an alarm indication in the event of a foreseeable functional failure in the equipment and installation arrangements. *See Pt 16, Ch 1, 2.4 Safety systems, general requirements 2.4.5*.

10.8.10 The oil mist detection system is to provide an indication that any lenses fitted in the equipment and used in determination of the oil mist level have been partially obscured to a degree that will affect the reliability of the information and alarm indication.

10.8.11 Where oil mist detection equipment includes the use of programmable electronic systems, the arrangements are to be in accordance with *Pt 16, Ch 1 Control Engineering Systems* as applicable.

10.8.12 Schematic layouts showing details and arrangements of oil mist detection and alarm systems are to be submitted. *See Pt 10, Ch 1, 1.4 Submission requirements*.

10.8.13 The equipment, together with detectors, is to be tested when installed on the test bed and on board the craft to demonstrate that the detection and alarm system functions correctly. The testing arrangements are to be to the satisfaction of the Surveyor.

10.8.14 Where sequential oil mist detection arrangements are provided, the sampling frequency and time is to be as short as reasonably practicable.

10.8.15 Where alternative methods are provided for the prevention of the build-up of oil mist that may lead to a potentially explosive condition within the crankcase, detailed information is to be submitted for consideration. The information is to include:

(a) Engine particulars – type, power, speed, stroke, bore and crankcase volume.
(b) Details of arrangements designed to prevent the build up of potentially explosive conditions within the crankcase, e.g. bearing temperature monitoring, oil splash temperature monitoring, crankcase pressure monitoring, and recirculation arrangements.
(c) Evidence to demonstrate that the arrangements are effective in preventing the build up of potentially explosive conditions together with details of in-service experience.
(d) Operating instructions and the maintenance and test instructions.

10.8.16 Where it is proposed to use the introduction of inert gas into the crankcase to minimise a potential crankcase explosion, details of the arrangements are to be submitted for consideration.

■ *Section 11*
Factory Acceptance Test and Shipboard Trials of Engines

11.1 Safety

11.1.1 Before any test is carried out, all relevant equipment for the safety of attending personnel is to be made available by the manufacturer/shipyard and is to be operational. This is to include crankcase explosive conditions protection, overspeed protection and any other shutdown function.

11.1.2 The overspeed protective device is to be set to a value which is not higher than the overspeed value that was demonstrated during the type test for that engine. This set point is to be verified by the Surveyor.

11.2 General

11.2.1 Engines which are to be subjected to trials on the test bed at the manufacturer's works and under attendance by the Surveyor(s) are to be tested in accordance with the scope of works trials specified in *Pt 10, Ch 1, 11.3 Works trials (factory acceptance test)*. The scope of the trials is to be agreed between LR and the manufacturer prior to testing.

11.2.2 Where multiple engines of the same design are manufactured, a quality assurance approach to approval may be applied if the manufacturer meets the requirements of and is registered on the Quality Assurance Scheme for Machinery (QAM). (*See Rules and Regulations for the Classification of Ships, July 2021 Pt 5, Ch 1, 6 Quality Assurance Scheme for Machinery*).

11.2.3 Before any official testing the engines are to be run in as prescribed by the engine manufacturer.

11.2.4 Adequate test bed facilities for loads as required in *Table 1.11.1 Scope of works trials for engines* are to be provided. All fluids used for testing purposes such as fuel, lubrication oil and cooling water are to be suitable for the purpose intended, e.g. they are to be clean, and if necessary pre-heated to achieve the recommended operating temperature. This applies to all fluids used temporarily or repeatedly for testing purposes only.

11.2.5 Survey of the engine is to include:

(a) Jacketing of high-pressure fuel oil lines including the system used for the detection of leakage.
(b) Screening of pipe connections in piping containing flammable liquids.
(c) Insulation of hot surfaces by taking random temperature readings that are to be compared with corresponding readings obtained during the type test. This is to be done while running at the maximum approved rating for the actual application. Use of contact thermometers may be accepted at the discretion of the attending Surveyor. If the insulation is modified subsequently to the Type Approval Test, LR may request more enhanced temperature measurements as required by the LR's Type Approval *Test Specification No. 4 – Type Testing of Reciprocating Internal Combustion Engines and Associated Ancillary Equipment*, Section 10.2.7 (*Fire Protection Measures*).

These surveys are normally to be made during the works trials, but at the discretion of LR parts of these surveys may be postponed to the shipboard testing.

11.2.6 Where the type test was not carried out on the complete engine, as described in the scope of this chapter, integration tests are to be conducted as part of the works or shipboard trials to confirm satisfactory operation of the complete engine. This includes satisfactory functioning on all fuel types on which the engine is to operate. *See also Pt 10, Ch 1, 11.4 Shipboard trials 11.4.6.*

11.2.7 For the duration of the acceptance test, no interventions or adjustments will be made to the machinery under test.

11.3 Works trials (factory acceptance test)

11.3.1 The purpose of the works trials is to verify design parameters such as power, fire protection and prevention arrangements, adherence to approved limits (e.g. maximum pressure) and functionality, and to establish reference values or base lines for later reference in the operational phase.

11.3.2 During testing the environmental conditions are to be recorded, including ambient air temperature, ambient air pressure and atmospheric humidity.

11.3.3 For each trial condition the parameters to be recorded include: power and speed; fuel index (or equivalent reading); maximum combustion pressures; exhaust gas temperature before turbine and from each cylinder (or from manifold, *see* Note 5 in *Table 1.7.1 Engines for propulsion purposes: alarms and safeguards slow-downs*); charge air temperature and pressure, and turbocharger speed (only for category B and C turbochargers).

11.3.4 For all stages of the works trials the pertaining operation values are to be measured and recorded by the engine manufacturer. All results are to be compiled in an acceptance protocol to be issued by the engine manufacturer. Where the engine designer requires through life monitoring of crankshaft deflections, such measurements are also to be taken before and after works acceptance trials in accordance with the engine designer's requirements.

11.3.5 In each case given in *Table 1.11.1 Scope of works trials for engines*, all measurements conducted at the various trial conditions are to be carried out at steady operating conditions. The readings for MCR, i.e. 100 per cent power (rated maximum continuous power at corresponding rpm) are to be taken twice at an interval of at least 30 minutes. For all trial conditions provision should be made for time needed by the Surveyor to carry out visual inspections.

11.3.6 Calibration records for the instrumentation are, upon request, to be presented to the attending Surveyor.

Table 1.11.1 Scope of works trials for engines

Trial condition	Duration	Note
Main engines driving propellers and waterjets		
Trial condition	Duration	Note
100 per cent power (rated power) at rated engine speed, *R*	≥ 60 minutes	-
110 per cent power at engine speed corresponding to 1,032**R*	15 minutes	or after having reached steady conditions, whichever is shorter, *see* Notes 1and 4
Approved intermittent overload (if applicable)	-	Testing for duration to be agreed with the manufacturer
90 per cent (of normal continuous power), 75 per cent, 50 per cent and 25 per cent power	-	Engines speed in accordance with the nominal propeller curve, sequence to be selected by the manufacturer
Reversing manoeuvres (if applicable)	-	-
Testing of governor and independent overspeed protective device	-	*See Pt 10, Ch 1, 7 Control and monitoring of main, auxiliary and emergency engines*
Shutdown device	-	*See Pt 10, Ch 1, 7 Control and monitoring of main, auxiliary and emergency engines*
Engines driving generators for electric propulsion or driving generators for auxiliary purposes		
Trial condition	Duration	Note
100 per cent power (rated power) at rated engine speed, *R*	≥ 60 minutes	-
110 per cent power	15 minutes	Or after having reached steady conditions *see* Note 2 For auxiliary engines, *see* Note 1
75 per cent, 50 per cent and 25 per cent power and idle run	-	*See* Note 2
Start-up tests	-	-
Testing of governor and independent overspeed protective device	-	*See Pt 10, Ch 1, 7.3 Auxiliary and emergency engine governors*
Shutdown device	-	*See Pt 10, Ch 1, 7.4 Overspeed protective devices*
Propulsion engines driving power take off (PTO) generator		
100 per cent power (rated power) at rated engine speed, *R*	≥ 60 minutes	-
110 per cent power	15 minutes	Or after having reached steady conditions, *see* Note 3
Approved intermittent overload (if applicable)	-	Testing for duration to be agreed with the manufacturer
90 per cent (or normal continuous power), 75 per cent, 50 per cent and 25 per cent power	-	Engine speed in accordance with the nominal propeller curve or at constant speed *R*, sequence to be selected by the manufacturer
Engines driving mechanical auxiliaries		
Trial condition	Duration	Note
100 per cent power (rated power) at rated engine speed, *R*	≥ 30 minutes	-
110 per cent power	15 minutes	Or after having reached steady conditions, *see* Note 1
Approved intermittent overload (if applicable)	-	Testing for duration to be agreed with the manufacturer

75 per cent, 50 per cent and 25 per cent power	-	Engine speed in accordance with the nominal power consumption curve, sequence to be selected by the manufacturer
Note 1. After running on the test bed, the fuel delivery system of main and auxiliary engines is normally to be so adjusted that overload power cannot be given in service unless intermittent overload power is approved by LR, in which case the limit is to be adjusted to that power. The setting of the restriction is to be made as applicable to the intended fuel. Any restriction settings, and other changes to the engine's fuel injection equipment required for operation on special fuels, are to be recorded and included by the engine manufacturer.		
Note 2. After running on the test bed, the fuel delivery system of diesel engines driving generators is to be adjusted so that full power plus a 10 per cent margin for transient regulation can be given in service after installation on board. The transient overload capability is required so that the required transient governing characteristics are achieved also at 100 per cent loading of the engine, and so that the protection system utilised in the electric distribution system can be activated before the engine stalls.		
Note 3. After running on the test bed, the fuel delivery system of propulsion engines also driving power take off (PTO) generators is to be adjusted so that full power plus a margin for transient regulation can be given in service after installation on board. The transient overload capability is required so that the electrical protection of downstream system components is activated before the engine stalls. This margin may be 10 per cent of the engine power but at least 10 per cent of the PTO power		
Note 4. Only required once for each different engine/turbocharger configuration.		

11.3.7 Calibration records for the instrumentation are, upon request, to be presented to the attending Surveyor.

11.3.8 Alternatives to the detailed tests may be agreed between the manufacturer and LR when the overall scope of tests is found to be equivalent. The scope of the trials may be expanded depending on the engine application, service experience, or other relevant reasons.

11.3.9 Turbocharger surge margin for propulsion engines is to be demonstrated as required by *Pt 10, Ch 1, 12.4 Matching with engine 12.4.2*

11.3.10 For electronically controlled engines:

(a) Factory acceptance tests in accordance with *Pt 10, Ch 1, 1.4 Submission requirements 1.4.2*;
(b) integration tests are to be made to verify that the response of the complete mechanical, hydraulic and electronic system is as predicted for all intended operational modes and the tests considered as a system are to be carried out at the works. If such tests are technically unfeasible at the works, then these tests may be conducted during sea trial; and
(c) verification of engine configuration, *see Pt 10, Ch 1, 4.3 Control engineering systems 4.3.2*, and that the approved software quality plans, including the software configuration management process, are being applied.

11.3.11 Checks of components to be presented for inspection after the works trials are left to the discretion of the Surveyor.

11.4 Shipboard trials

11.4.1 The purpose of the shipboard testing is to verify compatibility with power transmission and driven machinery in the system, safety, control and auxiliary systems necessary for the engine and integration of engine/shipboard control systems, as well as other items that had not been dealt with in the FAT (Factory Acceptance Testing).

11.4.2 After installation on board, engines are to undergo shipboard trials as specified in *Table 1.11.2 Scope of shipboard trials for engines*. The scope of the trials may be expanded depending on the engine application, service experience or other relevant reasons, and is to be agreed between the LR Surveyor and the Shipyard prior to testing.

Table 1.11.2 Scope of shipboard trials for engines

Main engines driving fixed-pitch propellers or waterjet (*see* Note 1)		
Trial condition	Duration	Note
At rated engine speed, *R*	≥ 4 hours	-
At engine speed corresponding to 1,032**R*	30 minutes	Where the engine adjustment permits, *see Pt 10, Ch 1, 11.2 General 11.2.7*
Approved intermittent overload (if applicable)	-	Testing for duration as agreed with the manufacturer
Minimum engine speed to be determined	-	-
Starting and reversing manoeuvres	-	*See Pt 10, Ch 1, 9 Starting arrangements* and *Pt 10, Ch 1, 13 Air compressors* (*see* Note 5)
Reverse direction of propeller rotation is to be demonstrated (during the dock or sea trials)	10 minutes	*See also Pt 10, Ch 1, 11.4 Shipboard trials 11.4.7* and *Pt 10, Ch 1, 11.4 Shipboard trials 11.4.8*
Control, monitoring, alarms and safety systems	-	Operation to be demonstrated
Where imposed, test to ensure engine can pass safely through barred speed range	-	*See Pt 10, Ch 1, 11.4 Shipboard trials 11.4.7* and *Pt 10, Ch 1, 11.4 Shipboard trials 11.4.8* for additional requirements in the case of a barred speed range
Main engines driving controllable pitch propellers		
Trial condition	Duration	Note
At 100 per cent power	≥ 4 hours	*See* Note 2
Approved intermittent overload (if applicable)	-	Testing for duration as agreed with the manufacturer
With reverse pitch suitable for manoeuvring	-	*See Pt 10, Ch 1, 11.4 Shipboard trials 11.4.7* and *Pt 10, Ch 1, 11.4 Shipboard trials 11.4.8* for additional requirements in the case of a barred speed range
Control, monitoring, alarm and safety systems	-	Operation to be demonstrated
Engine(s) driving generator(s) for electrical propulsion and/or main power supply		
Trial condition	Duration	Note
100 per cent power (rated electrical power of generator)	60 minutes	*See* Notes 3 and 4
110% power (rated electrical power of generator)	≥ 10 minutes	*See* Note 4
Starting manoeuvres	-	*See* Note 5
Control, monitoring, alarm and safety systems	-	Operation to be demonstrated
Demonstration of the generator prime movers' and governors' ability to handle load steps		*See Pt 10, Ch 1, 7.3 Auxiliary and emergency engine governors*
Propulsion engines driving power take off (PTO) generator		
Trial condition	Duration	Note
100 per cent engine power (MCR) at corresponding speed, *R*	≥ 4 hour	-
100 per cent propeller branch power at engine speed, *R* (unless already covered above)	2 hours	-
100 per cent PTO branch power at engine speed, *R*	≥ 1 hour	-
Control, monitoring, alarm and safety systems	-	Operation to be demonstrated

Engines driving mechanical auxiliaries		
Trial condition	Duration	Note
100 per cent engine power (MCR) at corresponding speed, *R*	≥ 30 minutes	–
Approved intermittent overload (if applicable)	-	Testing for duration as approved
Control, monitoring, alarm and safety systems	-	Operation to be demonstrated

Note 1. For main propulsion engines driving or reversing gears, the tests for main engines driving fixed-pitch propellers apply as appropriate.

Note 2. Controllable pitch propellers are to be tested with various propeller pitches. The 100 per cent power test is to be conducted at rated engine speed *R* with a propeller pitch set at MCR (or to the maximum achievable power if 100 per cent cannot be reached).

Note 3. The tests to be performed at rated speed with a constant governor setting.

Note 4. Tests are to be based on the rated electrical powers of the electric propulsion motors.

Note 5. Starting manoeuvres are to be carried out in order to verify the capacity of the starting media. The ability of reversible engines to be operated in the reverse direction is to be demonstrated. *See Pt 9, Ch 1, 4.7 Astern power* .

11.4.3 Engines driving electrical generators are to be tested either:

(a) at 100 per cent electrical power for at least 60 minutes and 110 per cent of rated electrical power of the generator for at least 10 minutes; or
(b) During the electrical propulsion plant test which requires testing with 100 per cent propulsion power (i.e. total electric motor capacity for propulsion) by distributing the power on as few generators as possible. The duration of this test is to be sufficient to reach stable operating temperatures of all rotating machines or for at least 4 hours.

11.4.4 Trials are to include demonstration of engine control, monitoring, alarm and safety system operation to confirm that they have been provided, installed and configured as intended and in accordance with the relevant requirements for main, auxiliary or emergency engines.

11.4.5 For electronically controlled engines:

(a) On board tests in accordance with the approved schedule, *see also Pt 10, Ch 1, 1.4 Submission requirements 1.4.2*; and
(b) verification of engine configuration, *see Pt 10, Ch 1, 4.3 Control engineering systems 4.3.2* and *Pt 10, Ch 1, 1.4 Submission requirements 1.4.3*, and that the approved software quality plans, including the software configuration management process, are being applied.

11.4.6 The suitability of an engine to burn residual or other special fuels is to be demonstrated, where the machinery installation is arranged to burn such fuels in service. Dual- or multi-fuel engines are to be tested on all fuels that the engine is specified to use. Where engines operate on a mix of different fuels then this is to be demonstrated. *See also Pt 16, Ch 1, 7.2 Unattended machinery space operation - UMS notation 7.2.1*.

11.4.7 For both manual and automatic engine control systems acceleration and deceleration through any barred speed range, is to be demonstrated. The transit times are to be equal or less than the times stated in the approved documentation and are to be recorded. This also applies when passing through the barred speed range in reverse rotational direction, especially during the stopping test. The ship’s draft and speed during all these demonstrations are to be recorded. Where a controllable pitch propeller is fitted, the pitch is also to be recorded.

11.4.8 The engine is to be checked for stable running (steady fuel index) at both upper and lower borders of the barred speed range. Steady fuel index means an oscillation range less than five per cent of the effective stroke (idle to full index).

11.4.9 In addition to the tests listed in *Table 1.11.2 Scope of shipboard trials for engines*, other tests may also be required by statutory regulations (e.g. the testing of exhaust gas emissions is to comply with *MARPOL - International Convention for the Prevention of Pollution from Ships* as applicable).

11.5 Additional Shipboard Trial requirements

11.5.1 At the discretion of the attending Surveyor, the scope of the trials may be expanded in consideration of special operating conditions, such as towing, trawling, etc.

■ Section 12
Turbochargers

12.1 General

12.1.1 Turbochargers are to be approved, either separately or as a part of an engine.

12.1.2 The requirements escalate with the size of the turbochargers. The parameter for size is the engine power (at MCR) supplied by a group of cylinders served by the actual turbocharger, e.g. for a V-engine with one turbocharger for each bank, the size is half of the total engine power. Turbochargers are categorised in three groups depending on served power by cylinder groups with:

(a) Category A: ≤ 1000 kW

(b) Category B: > 1000 kW and ≤ 2500 kW

(c) Category C: > 2500 kW

12.1.3 Plans and particulars are to be submitted as required by *Pt 10, Ch 1, 1.4 Submission requirements 1.4.4*.

12.1.4 Alarms and slowdowns for turbochargers are required as listed in *Table 1.7.1 Engines for propulsion purposes: alarms and safeguards slow-downs* and *Table 1.7.3 Auxiliary engine alarms and safeguards*.

12.1.5 Turbochargers are to be designed for the operating conditions defined in *Pt 9, Ch 1, 4 Operating conditions*. The component lifetime and the alarm level for speed are to be based on 45°C air inlet temperature.

12.1.6 Category B and C turbochargers (new turbocharger types or developments of existing types) are to be Type Approved. A Type test, *see Pt 10, Ch 1, 14.2 Turbochargers*, is to be carried out on a standard unit taken from the assembly line and is to be witnessed by the Surveyor.

12.1.7 The air inlet of turbochargers is to be fitted with a filter.

12.2 Works testing and inspection

12.2.1 LR Surveyors are to be provided with free access to the manufacturer's works to inspect, at random, the quality control measures and to witness the tests required by *Pt 10, Ch 1, 12.2 Works testing and inspection 12.2.3* as deemed necessary, and to have free access to all control records and subcontractor's certificates.

12.2.2 Each individual unit is to be tested in accordance with *Pt 10, Ch 1, 12.2 Works testing and inspection 12.2.4* to *Pt 10, Ch 1, 12.2 Works testing and inspection 12.2.8*. For category C turbochargers these tests are to be conducted under survey unless an alternative approach for product assurance has been approved by LR. For category B turbochargers the testing is to be documented by manufacturer's certificate. For category A turbochargers, test results, documented by manufacturer's certificate, are only required if specifically requested by LR.

12.2.3 Rotating parts of the turbocharger's blower are to be marked for easy identification with the corresponding certificate. Component identification is to be in accordance with the *Rules for the Manufacture, Testing and Certification of Materials, July 2021*.

12.2.4 Material tests (chemical composition and mechanical properties) and dimensional inspection, of the rotating parts and casing are to confirm compliance with the approved design and material specifications (*Pt 10, Ch 1, 1.4 Submission requirements 1.4.4*). Testing and inspection of turbocharger casings and rotor shafts are to comply with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials, July 2021* as applicable.

12.2.5 Cooling spaces are to be hydraulically tested to 0,4 MPa gauge or 1,5 times maximum working pressure, whichever is higher.

12.2.6 Rotating parts are to be subjected to ultrasonic testing and surface crack detection (magnetic particle testing is to be carried out on ferro-magnetic materials, penetrant testing is only to be carried out on non-ferritic materials). Ultrasonic testing is not required for components manufactured from cast iron.

12.2.7 All rotors are to be dynamically balanced on final assembly.

12.2.8 All compressor wheels are to be overspeed tested for three minutes at either 20 per cent above the alarm level speed at room temperature, or 10 per cent above alarm level speed at 45°C inlet temperature when tested in the actual housing with the

corresponding pressure ratio. The overspeed test may be waived for forged wheels that are individually controlled by an approved non-destructive method. This test will not be waived for wheels of the unit to be type tested.

12.3 Certification

12.3.1 Turbochargers are to be delivered with:

(a) Category B turbochargers: A manufacturer's certificate, which states the applicable type approval, including production assessment.
(b) Category C turbochargers: An LR certificate or LR Quality Scheme Product Certificate as applicable, which states the applicable Type Approval and LR Quality Scheme reference, if applicable.

12.3.2 Where the manufacturer operates an alternative approach for product assurance approved by LR the periodic audits will include specific focus on:

(a) Chemical composition of material for the rotating parts.
(b) Mechanical properties of the material of a representative specimen for the rotating parts and the casing.
(c) UT and crack detection of rotating parts.
(d) Dimensional inspection of rotating parts.
(e) Rotor dynamic balancing.
(f) Hydraulic testing of cooling spaces in accordance with as per *Pt 10, Ch 1, 12.2 Works testing and inspection 12.2.5*.
(g) Overspeed test of all compressor disks as per *Pt 10, Ch 1, 12.2 Works testing and inspection 12.2.8*

12.3.3 The above certification and test requirements also apply to replacement rotating parts and casing.

12.4 Matching with engine

12.4.1 Turbochargers are to have a compressor characteristic that allows the engine on which it is installed to operate without surging during all operating conditions. For abnormal, but permissible, operation conditions, such as misfiring and sudden load reduction, no continuous surging is to occur.

Note Surging and continuous surging are defined as follows: Surging means any phenomenon, which results in a high pitch vibration of an audible level or explosion-like noise from the scavenger area of the engine. Continuous surging means that surging happens repeatedly and not only once.

12.4.2 Category C turbochargers used on propulsion engines are to be tested to ensure an adequate operating margin without surge occurring during the engine works trials as specified below. These tests may be waived if successfully tested earlier on an identical configuration of engine and turbocharger (including same nozzle rings).

(a) For trunk piston engines the following are to be performed without indication of surging:
    (i) With maximum continuous power and speed (i.e. 100 per cent), the speed is to be reduced with constant torque (fuel index) down to 90 per cent power.
    (ii) With 50 per cent power at 80 per cent speed (i.e. propeller characteristic for fixed pitch), the speed is to be reduced to 72 per cent while keeping constant torque (fuel index).
(b) For crosshead engines the surge margin is to be demonstrated by at least one of the following methods:
    (i) The engine working characteristic established at workshop testing of the engine is to be plotted into the compressor chart of the turbocharger (established in a test rig). There is to be at least a 10 per cent surge margin in the full load range, i.e. the working flow is to be at least 10 per cent above the theoretical (mass) flow at the surge limit (at no pressure fluctuations).
    (ii) Sudden fuel shut-off to at least one cylinder is to not result in continuous surging and the turbocharger(s) is/are to stabilise at the new load within 20 seconds. For applications with more than one turbocharger, the fuel is to be shut-off to the cylinders immediately upstream of each turbocharger. This test is to be performed at two different engine loads:

- The maximum power permitted with one cylinder misfiring.
- The engine load corresponding to a charge air pressure of about 0,6 bar (but without auxiliary blowers running).

    (iii) Sudden power reduction from 100 per cent to 50 per cent of the maximum continuous power is not to result in continuous surging and the turbocharger(s) is/are to be stabilised at the new load within 20 seconds.

Section 13
Air compressors

13.1 General Requirements

13.1.1 The requirements of this Section are applicable to reciprocating air compressors intended for starting main engines and auxiliary engines providing essential services.

13.1.2 Two or more air compressors are to be fitted having a total capacity, together with a topping-up compressor where fitted, capable of charging the air receivers within one hour from atmospheric pressure, to the pressure sufficient for the number of starts required by *Pt 10, Ch 1, 9.2 Air receiver capacity* . At least one of the air compressors is to be independent of the main propulsion unit and the capacity of the main air compressors is to be approximately equally divided between them. The capacity of an emergency compressor which may be installed to satisfy the requirements of *Pt 10, Ch 1, 9.1 Dead ship condition starting arrangements* is to be ignored.

13.1.3 The compressors are to be so designed that the temperature of the air discharged to the starting air receivers will not substantially exceed 93°C in service. A small fusible plug or an alarm device operating at 121°C is to be provided on each compressor to give warning of excessive air temperature. The emergency air compressor is excepted from these requirements.

13.1.4 Each compressor is to be fitted with a safety valve so proportioned and adjusted that the accumulation with the outlet valve closed will not exceed 10 per cent of the maximum working pressure. The casings of the cooling water spaces are to be fitted with a safety valve or bursting disc so that ample relief will be provided in the event of the bursting of an air cooler tube. It is recommended that compressors be cooled by fresh water.

13.1.5 Each compressor is to be fitted with an alarm for failure of the lubricating oil supply which will initiate an automatic shutdown.

13.2 Plans and particulars

13.2.1 Detailed plans, particulars, dimensional drawings and material specifications for compressor crankshafts are to be submitted. Plans and particulars for other parts and calculations where applicable are to be submitted to LR upon request.

13.2.2 Where compressors of a special type or design are proposed, the requirements of *Pt 5, Ch 14 Machinery Piping Systems* of the *Rules and Regulations for the Classification of Ships, July 2021* are to be applied.

13.3 Materials

13.3.1 The specified minimum tensile strength of castings and forgings for compressor crankshafts are to be within the limits given in *Pt 10, Ch 1, 2.1 Crankshaft materials 2.1.1* and for grey cast iron to be not less than 300 N/mm^2

13.3.2 Where it is proposed to use materials outside the ranges specified in *Pt 10, Ch 1, 13.3 Materials 13.3.1*, details of the chemical composition, heat treatment and mechanical properties are to be submitted for approval.

13.3.3 For compressors crankshafts with a calculated crank pin diameter equal to or greater than 50 mm, materials for components are to be manufactured and tested in accordance with the requirements of the LR Rules for Materials and *Table 1.2.1 Summary of testing and associated documentation for engine components*. For calculated crank pin diameters less than 50 mm, a manufacturers' certificate may be accepted, *seeCh 1, 3.1 General 3.1.3* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2021*.

13.4 Design and Construction

13.4.1 A fully documented fatigue strength analysis is to be submitted indicating a factor of safety of 1,5 at the design loads based on a suitable fatigue strength criterion. Alternatively, the requirements of *Pt 10, Ch 1, 13.4 Design and Construction 13.4.2Pt 10, Ch 1, 13.4 Design and Construction 13.4.2* to *Pt 10, Ch 1, 13.4 Design and Construction 13.4.6* may be used.

13.4.2 The diameter, d_p, of a compressor crankshaft is to be not less than d, determined by the following formula, when all cranks on the shaft are located between two main bearings only:

$$d = V_c\left(\frac{D^2 pZ}{78,5}\left(\frac{S}{16} + \frac{ab}{a+b}\right)\right)^{\frac{1}{3}} \text{ mm}$$

where

a = distance between inner edge of one main bearing and the centreline of the crankpin nearest the centre of the span, in mm

b = distance from the centreline of the same crankpin to the inner edge of the adjacent main bearing, in mm

$a+b$ = span between inner edges of main bearings, in mm

d_p = proposed minimum diameter of crankshaft, in mm

p = design pressure, in MPa g, as defined in *Pt 15, Ch 1, 4.1 Design symbols 4.1.1*

D = diameter of cylinder, in mm

S = length of stroke, in mm

V_c = 1,0 for shafts having one cylinder per crank, or

$$\left.\begin{array}{l} = 1{,}05 \text{ for } 90° \\ = 1{,}18 \text{ for } 60° \\ = 1{,}25 \text{ for } 45° \end{array}\right\} \text{between adjacent cylinders on the same crankpin}$$

for the shaft and cylinder arrangements as detailed in *Table 1.13.1 Angle between cylinders*.

$Z = \dfrac{560}{\sigma_u + 160}$ for steel

$Z = \dfrac{700}{\sigma_u + 260 - 0{,}059 d_p}$ for spheroidal or nodular graphite cast iron

$Z = \dfrac{700}{\sigma_u + 260 - 0{,}069 d_p}$ for grey cast iron

σ_u = specified minimum tensile strength of crankshaft material, in N/mm^2.

Table 1.13.1 Angle between cylinders

Number of crankpins	Number of cylinders per crank	Angle between cylinders, in degrees		
1 or 2	2	45	60	90
3	2	45	60	—
4	2	45	60	—
1	3	45	60	90
2	3	45	60	—
3	3	45	—	—
1	4	45	60	—
2	4	45	—	—

13.4.3 Where the shaft is supported additionally by a centre bearing, the diameter is to be evaluated from the half shaft between the inner edges of the centre and outer main bearings. The diameter so found for the half shaft is to be increased by six per cent for the full length shaft diameter.

13.4.4 The dimensions of crankwebs are to be such that Bt^2 is to be not less than given by the following formulae:

$0{,}4d^3$ for the web adjacent to the bearing

$0{,}75d^3$ for intermediate webs

where

B = breadth of web, in mm

d = minimum diameter of crankshaft as required by *Pt 10, Ch 1, 13.4 Design and Construction 13.4.2* in mm

t = axial thickness of web which is to be not less than 0,45d for the web adjacent to the bearing, or 0,60d for intermediate webs, in mm.

13.4.5 Fillets at the junction of crankwebs with crankpins or journals are to be machined to a radius not less than 0,05d. Smaller fillets, but of a radius not less than 0,025d, may be used provided the diameter of the crankpin or journal is not less than cd,

where

c = 1,1 – $2^{r/d}$ but to be taken as not less than 1,0

d = minimum diameter of crankshaft as required by *Pt 10, Ch 1, 13.4 Design and Construction 13.4.2* in mm

r = fillet radius, in mm.

13.4.6 Fillets and oil holes are to be rounded to an even contour and smooth finish.

13.4.7 An oil level sight glass or oil level indicator is to be fitted to the crankcase.

13.4.8 The crankcases of compressors are to be designed to withstand a pressure equal to the maximum working pressure of the system.

13.4.9 Compressors with shaft power exceeding 500 kW are to have torsional vibration analysis determined in accordance with *Pt 13, Ch 1 Torsional Vibration* as applicable.

13.4.10 The cooler dimensions for sea-water cooled stage air coolers are to be based on an inlet temperature of not less than 32°C. Where fresh water cooling is used, the cooling water inlet temperature is not to be greater than 40°C.

13.4.11 The cooler dimensions for air cooled stage air coolers are to be based on an air temperature of not less than 45°C.

13.4.12 The piping to and from the air compressor is to be arranged to prevent condensation from entering the cylinders.

13.5 Testing

13.5.1 Cast Iron crankshafts for air compressors are to be manufactured and tested in accordance with the *Rules for the Manufacture, Testing and Certification of Materials, July 2021*, *Ch 7, 5 Iron castings for crankshafts*. Crankshafts for air compressors manufactured from other materials are to be tested in accordance with the applicable requirements of the *Rules for the Manufacture, Testing and Certification of Materials, July 2021*. Ultrasonic testing is not required for components manufactured from cast iron.

13.5.2 Cylinders, covers and liners of air compressors are to be subjected to hydraulic pressure tests at 1,5 times the final pressure of the stage concerned.

13.5.3 The compressed air chambers of the intercoolers and aftercoolers of air compressors are to be subjected to hydraulic pressure tests at 1,5 times the final pressure of the stage concerned.

13.5.4 Manufacturer's certification for materials and pressure testing will be accepted for air compressors with a calculated crankpin diameter of less than 50 mm.

13.5.5 After construction all compressors are to be subjected to a running test to the satisfaction of the attending Surveyor.

13.6 Safety arrangements and monitoring

13.6.1 Air compressors are to be arranged and located so as to minimise the intake of air contaminated by oil or water.

13.6.2 Where one compressor stage comprises several cylinders, which can be shut off individually, each cylinder shall be equipped with a safety valve and a pressure gauge.

13.6.3 After the final stage, all air compressors are to be equipped with a water trap and after-cooler. The water traps, after-coolers and the compressed air spaces between the stages are to be provided with discharge devices at their lowest points.

13.6.4 Each compressor stage shall be fitted with a suitable pressure gauge, the scale of which must indicate the relevant maximum permissible working pressure.

13.7 Crankcase relief valves

13.7.1 In compressors having cylinders not exceeding 200 mm bore or having a crankcase gross volume not exceeding 0,6 m^3, crankcase relief valves may be omitted.

13.7.2 Crankcases are to be provided with lightweight spring-loaded valves or other quick-acting and self-closing devices to relieve the crankcases of pressure in the event of an internal explosion and to prevent any inrush of air thereafter. The valves are to be designed and constructed to open quickly and be fully open at a pressure not greater than 0,02 MPa.

13.7.3 The valve lids are to be made of ductile material capable of withstanding the shock of contact with stoppers at the full open position.

13.7.4 Each valve is to be fitted with a flame arrester that permits flow for crankcase pressure relief and prevents the passage of flame following a crankcase explosion.

13.7.5 The valves are to be provided with a copy of the manufacturer's installation and maintenance manual for the size and type of valve being supplied. The manual is to contain the following information:

(a) Description of valve with details of function and design limits.
(b) Copy of type test certification.
(c) Installation instructions.
(d) Maintenance and in-service instructions to include testing and renewal of any sealing arrangements.
(e) Actions required after a crankcase explosion.

13.7.6 A copy of the installation and maintenance manual required by *Pt 10, Ch 1, 13.7 Crankcase relief valves 13.7.5* is to be provided on board the ship.

13.7.7 Plans showing details and arrangements of the crankcase relief valves are to be submitted for approval, *see Pt 10, Ch 1, 1.4 Submission requirementsPt 10, Ch 1, 1.4 Submission requirements.*

13.7.8 The valves are to be provided with suitable markings that include the following information:

(a) Name and address of manufacturer.
(b) Designation and size.
(c) Month/year of manufacture.
(d) Approved installation orientation.

13.8 Number of crankcase relief valves

13.8.1 In compressors that have cylinders exceeding 200 mm but do not exceed 250 mm bore, at least two relief valves are to be fitted; where more than one relief valve is required, the valves are to be located at or near the ends of the crankcase.

13.8.2 In compressors that have cylinders exceeding 250 mm but do not exceed 300 mm bore, at least one relief valve is to be fitted in way of each alternate crankthrow with a minimum of two valves. For compressors having 3, 5, 7, 9, etc. crankthrows, the number of relief valves is not to be less than 2, 3, 4, 5, etc. respectively.

13.8.3 In compressors that have cylinders exceeding 300 mm bore, at least one valve is to be fitted in way of each main crankthrow.

13.8.4 Additional relief valves are to be fitted for separate spaces on the crankcase, such as gear or chain cases, when the gross volume of such spaces exceeds 0,6 m^3.

13.9 Size of crankcase relief valves

13.9.1 The combined free area of the crankcase relief valves fitted on a compressor is to be not less than 115 cm2/m3 based on the volume of the crankcase.

13.9.2 The free area of each relief valve is to be not less than 45 cm^2.

13.9.3 The free area of the relief valve is the minimum flow area at any section through the valve when the valve is fully open.

13.9.4 In determining the volume of the crankcase for the purpose of calculating the combined free area of the crankcase relief valves, the volume of the stationary parts within the crankcase may be deducted from the total internal volume of the crankcase.

13.10 Vent pipes

13.10.1 Where crankcase vent or breather pipes are fitted, they are to be made as small as practicable and/or as long as possible to minimise the inrush of air after an explosion.

■ *Section 14* Type testing – General

14.1 Engines

14.1.1 New engine types or developments of existing types are to be subjected to an agreed programme of type testing to complement the design appraisal and review of documentation.

14.1.2 Requirements for type testing of engines are contained within the Lloyd's Register Type Approval System, *Test Specification No.4 – Type Testing of Reciprocating Internal Combustion Engines and Associated Ancillary Equipment*. In all cases the type test specification is to be agreed with LR.

14.1.3 Type testing specifications for other auxiliary systems are to be submitted for approval if they are to be tested separately from the engine.

14.1.4 Wherever practical, type tests are to be conducted with the engine control systems operational in the approved configuration, *see* Pt 10, Ch 1, *1.3 Submission requirements* and *Pt 10, Ch 1, 4.3 Control engineering systems, 4.3.2*. Configuration management documents that satisfy the requirements of ISO 10007 (or an equivalent national or international standard) are to be reviewed at testing for validity and referenced in the type test report.

14.1.5 In addition to type testing against the requirements of *Test Specification No. 4 – Type Testing of Reciprocating Internal Combustion Engines and Associated Ancillary Equipment*, engines may also be submitted for approval against recognised international or national standards. Where this additional testing and appraisal is carried out satisfactorily, it will be stated on the Type Approval Certificate.

14.1.6 A type test carried out for a particular type of engine at any place of manufacture will be accepted for all engines of the same type built by licensees or the licensor, subject to each place of manufacture being found to meet LR requirements for conformity of production.

14.2 Turbochargers

14.2.1 Requirements for type testing of category B and C turbochargers are contained within the Lloyd's Register Type Approval System, *Test Specification No. 4 – Type Testing of Reciprocating Internal Combustion Engines and Associated Ancillary Equipment*. In all cases the type test specification and testing plan are to be agreed with LR.

14.3 Crankcase explosion relief valves

14.3.1 Requirements for type testing of crankcase explosion relief valves are contained within the Lloyd's Register Type Approval System, *Test Specification No. 4 – Type Testing of Reciprocating Internal Combustion Engines and Associated Ancillary Equipment*. In all cases the type test specification is to be agreed with LR.

14.3.2 The test specification is only applicable to explosion relief valves fitted with flame arresters. Where internal oil wetting of a flame arrester is a design feature of an explosion relief valve, alternative testing arrangements that demonstrate compliance with these requirements may be proposed by the manufacturer. The alternative testing arrangements are to be submitted to LR for appraisal.

14.4 Crankcase oil mist detection system

14.4.1 Requirements for type testing of crankcase oil mist detection systems are contained within the Lloyd's Register Type Approval System, *Test Specification No. 4 – Type Testing of Reciprocating Internal Combustion Engines and Associated Ancillary Equipment*. In all cases the type test specification is to be agreed with LR.

14.4.2 This test specification is also applicable to oil mist detection systems intended for gear cases.

14.4.3 The approval of one type of detection equipment may be used to qualify other devices having identical construction details. Proposals are to be submitted for consideration.

14.4.4 Acceptance of crankcase oil mist detection equipment is at the discretion of LR based on the appraisal of plans and particulars and the test house report of the results of type testing. *See Pt 10, Ch 1, 1.4 Submission requirements 1.4.6Pt 10, Ch 1, 1.4 Submission requirements 1.4.6.*

■ *Section 15*

Requirements for craft which are not required to comply with the HSC Code

15.1 General

15.1.1 Unless specifically stated as exempt by the contents of this Section, the following requirements apply to craft which are not required to comply with the HSC code:

- *Pt 10, Ch 1, 1 General requirements* to *Pt 10, Ch 1, 3 Crankshaft design*
- *Pt 10, Ch 1, 5 Construction and welded structures*
- *Pt 10, Ch 1, 7 Control and monitoring of main, auxiliary and emergency engines* to *Pt 10, Ch 1, 10 Safety arrangements*

15.1.2 The requirements of *Pt 9, Ch 1, 4.2 Inclinations of the craft 4.2.1* do not apply to yachts or service craft less than 24 m.

15.1.3 The requirements of *Pt 10, Ch 1, 14.1 Engines* do not apply to service craft less than 24 m.

15.2 Details to be submitted

15.2.1 The requirements of *Pt 10, Ch 1, 1.4 Submission requirements Table 1.1.1 Plans and particulars to be submitted* do not apply to yachts or service craft less than 24 m, *see Pt 9, Ch 1, 6.1 Plans and particulars*.

15.2.2 The requirements of (FMEA as detailed in *Pt 9, Ch 1, 2.3 Calculations and specifications 2.3.8*) do not apply to yachts or to service craft less than 24 m unless used for passenger carrying duties.

15.3 Materials

15.3.1 Materials for which no provision is made in this part of the Rules may be accepted provided that they comply with an approved specification and such tests as may be considered necessary.

15.4 Crankshaft design

15.4.1 The requirements of *Pt 10, Ch 1, 3 Crankshaft design* do not apply to the following types of craft having main or auxiliary diesel engines with a power output not exceeding 110 kW:

(a) service craft of less than 24 m,
(b) yachts,
(c) ACVs.

■ *Section 1*
General requirements

1.1 Application

1.1.1 This Chapter is to be read in conjunction with the General Requirements for Machinery in *Pt 9 General Requirements for Machinery*.

1.1.2 The requirements of this Chapter are applicable to gas turbines for main propulsion and essential auxiliary services.

1.2 Power ratings

1.2.1 In this Chapter, where the dimensions of any particular component are determined from shaft power, *P*, in kW, and revolutions per minute, *R*, the values to be used are those defined in *Pt 9 General Requirements for Machinery*.

1.3 Power conditions for generator sets

1.3.1 Auxiliary gas turbines coupled to electrical generators are to be capable under service conditions of developing continuously the power to drive the generators at full rated output and of developing for a short period (15 minutes) an overload power of not less than 10 per cent, *see Pt 16, Ch 2 Electrical Engineering*.

1.4 Inclination of craft

1.4.1 Main and essential auxiliary gas turbines are to operate satisfactorily under the conditions as shown in *Table 1.4.1 Inclinations*.

■ *Section 2*
Particulars to be submitted

2.1 Plans and information

2.1.1 At least three copies of the following plans are to be submitted.

- Sectional assembly.
- Casings.
- Combustion chambers and heat exchangers.
- Rotors, bearings and couplings.

- Blades and blade attachments.
- Inlet and exhaust ducting.
- Securing arrangement (including details of resilient mounts where applicable).
- Control engineering aspects in accordance with *Pt 16, Ch 1 Control Engineering Systems*.
- Fuel oil system schematic, including controls and safety devices.
- Lubricating oil system schematic.
- Starting system schematic.
- Cooling water system schematic, where applicable.

2.1.2 The following information and calculations are to be submitted.

(a) Details of the acoustic enclosure fire detection and extinguishing system, where applicable.
(b) Power/speed operational envelope.

Calculations and information for short term high power operation, where applicable.

Operation and Maintenance Manuals.
(c) Calculations of the critical speeds of blade and rotor vibration, giving full details of the basic assumptions.

An analysis of the effect of a rotor blade failure and any details of service experience, *see Pt 10, Ch 2, 4.3 Containment*.
(d) High temperature characteristics of the materials, where applicable, including (at the working temperatures) the associated creep rate and rupture strength for the designed service life, fatigue strength, corrosion resistance and scaling properties.

Particulars of heat treatment, including stress relief, where applicable.

Material specifications covering the listed components together with details of any surface treatments, non-destructive testing and hydraulic tests.

2.1.3 The most onerous pressures and temperatures to which each component may be subjected are to be indicated on plans or provided as part of the design specification.

2.1.4 Calculations of the steady state stresses, including the effect of stress raisers, etc. in the turbine and compressor rotors and blading at the maximum speed and temperature in service are to be submitted. Such calculations should indicate the designed service life and be accompanied, where possible, by test results substantiating the limiting criteria.

2.1.5 Details of calculations and tests to establish the service life of other stressed parts, including gearing (where applicable), bearings, seals, etc. are also to be submitted. All calculations and tests should take account of all relevant environmental factors including particular type of service and fuel intended to be used.

2.1.6 Components fabricated by means of welding will be considered for acceptance if constructed by firms whose works are properly equipped to undertake welding of the standards appropriate to the components. Details are to be submitted for consideration.

2.1.7 Before work is commenced, manufacturers are to submit for consideration details of proposed welding procedures and their proposals for routine examination of joints by non-destructive means.

2.1.8 The manufacturer's proposals for testing the gas turbine are to be submitted for consideration.

2.1.9 A Failure Mode and Effects Analysis (FMEA) is to be submitted as detailed in *Pt 9 General Requirements for Machinery*.

■ *Section 3* **Materials**

3.1 Materials for forgings

3.1.1 Rotors and discs are to be of forged steel. For carbon and carbon-manganese steel forgings, the specified minimum tensile strength is to be selected within the limits of 400 and 600 N/mm^2. For alloy steel rotor forgings, the specified minimum tensile strength is to be selected within the limits of 500 and 800 N/mm^2. For discs and other alloy steel forgings, the specified minimum tensile strength is to be selected within the limits of 500 and 1000 N/mm^2. *See also Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

3.1.2 For alloy steels, specifications giving the proposed chemical composition and heat treatment are to be submitted for approval.

3.1.3 When it is proposed to use a material of higher tensile strength, full details are to be submitted for approval.

3.1.4 Components of non-ferrous construction should be submitted for consideration, together with full details of materials to be used and method of fabrication.

3.2 Material tests and inspection

3.2.1 Components are to be tested in accordance with the relevant requirements of the *Rules for the Manufacture, Testing and Certification of Materials, July 2021*.

3.2.2 For components of novel design special consideration will be given to the material test and non-destructive testing requirements.

■ *Section 4* Design

4.1 General

4.1.1 All parts of turbines, compressors, etc. are to have clearances and fits consistent with adequate provision for the relative thermal expansion of the various components. Special attention is to be given to minimising casing and rotor distortion under all operating conditions.

4.1.2 Turbine bearings are to be so disposed and supported that lubrication is not adversely affected by heat flow from adjacent hot parts. Effective means are to be provided for intercepting oil leakage and preventing oil from reaching high temperature glands and casings.

4.2 Vibration

4.2.1 Care is to be taken in the design and manufacture of turbine and compressor rotors, rotor discs and rotor blades to ensure freedom from undue vibration within the operating speed range. Where critical speeds are found by calculation to occur within the operating speed range, vibration measurements may be requested in order to verify the calculations, *see Pt 13 Shaft Vibration and Alignment*.

4.3 Containment

4.3.1 Gas turbines are to be designed and installed so as to contain debris in the event of an internal failure.

4.3.2 The gas turbine is to be located such that any flying debris resulting from a failure will not endanger the craft, other machinery, occupants of the craft or any other persons.

4.3.3 Where an acoustic enclosure is fitted which completely surrounds the gas generator and the high pressure oil pipes, a fire detection and extinguishing system is to be provided for the acoustic enclosure.

4.4 External influences

4.4.1 Pipes and ducting connected to casings are to be so designed that no excessive thrust loads or moments are applied by them to the compressors and turbines.

4.4.2 Platform gratings and fittings in way of the supports are to be so arranged that casing expansion is not restricted.

4.4.3 Where main turbine seatings incorporating a tank structure are proposed, consideration is to be given to the temperature variation of the tank in service to ensure that turbine alignment will not be adversely affected.

4.4.4 For securing arrangements, including resilient mounting, *see Pt 9, Ch 1 General Requirements for Machinery*.

Section 5
Construction

5.1 Welded components

5.1.1 All welded construction is to be in accordance with the requirements specified in *Ch 13 Requirements for Welded Construction* of the Rules for Materials.

5.1.2 Major joints are to be designed as full-strength welds and for complete fusion of the joint.

5.1.3 Stress relief heat treatment is to be applied to all cylinders, rotors and associated components on completion of the welding of all joints and attached structures, *see Pt 15 Piping Systems and Pressure Plant*.

Section 6
Starting arrangements

6.1 Initial starting arrangements

6.1.1 Equipment for starting main and auxiliary turbines is to be provided and arranged such that the necessary initial charge of starting air or initial electric power can be developed on board the craft without external aid. If for this purpose an emergency air compressor or electric generator is required, these units are to be power driven by manually started oil engines except in the case of small installations where a hand operated compressor of approved capacity may be accepted. Alternatively, other devices of approved type may be accepted as a means of providing the initial start, *see also Pt 16, Ch 2, 2.4 Prime mover governors 2.4.2*.

6.2 Purging before ignition

6.2.1 Means are to be provided, preferably automatic or interlocked, to clear all parts of the gas turbine of the accumulation of fuel oil or for purging gaseous fuel before ignition commences on starting, or recommences after failure to start. The purge is to be of sufficient duration to displace at least three times the volume of the exhaust system.

6.3 Air starting

6.3.1 Where the gas turbine is arranged for air starting the total air receiver capacity is to be sufficient to provide, without replenishment, not less than six consecutive starts. At least two air receivers of approximately equal capacity are to be provided. For scantlings and fittings of air receivers, *see Pt 15 Piping Systems and Pressure Plant*.

6.3.2 For multi-engine installations three consecutive starts per engine are required.

6.4 Electric starting

6.4.1 Where main turbines are fitted with electric starters, two batteries are to be fitted. Each battery is to be capable of starting the turbines when cold and the combined capacity is to be sufficient without recharging to provide the number of starts of the main turbines as required by *Pt 10, Ch 2, 6.3 Air starting*.

6.4.2 Electric starting arrangements for auxiliary turbines are to have two separate batteries or be supplied by separate circuits from the main turbine batteries when such are provided. Where one of the auxiliary turbines only is fitted with an electric starter one battery will be acceptable.

6.4.3 The combined capacity of the batteries for starting the auxiliary turbines is to be sufficient for at least three starts for each turbine.

6.4.4 The requirements for battery installations are given in *Pt 16, Ch 2 Electrical Engineering*.

Section 7
Piping systems

7.1 General

7.1.1 Gas turbine piping systems are, in general, to comply with the requirements given in *Pt 15, Ch 1 Piping Design Requirements* and *Pt 15, Ch 3 Machinery Piping Systems*, due regard being paid to the particular type of installation.

7.1.2 Synthetic rubber hoses, with single or double closely woven integral wire braid reinforcement, or convoluted metal pipes with wire braid protection, may be used in compressed air, fresh water, sea-water, fuel oil and lubricating oil systems. Where synthetic rubber hoses are used for fuel or supply to burners, the hoses are to have external wire braid protection in addition to the integral wire braid.

7.2 Fuel oil systems

7.2.1 Fuel oil arrangements are to comply with the requirements of *Pt 15, Ch 3 Machinery Piping Systems*.

7.2.2 Two or more filters are to be fitted in the fuel oil supply lines to the main and auxiliary turbines, and the arrangements are to be such that any filter can be cleaned without interrupting the supply of filtered fuel oil to the turbines.

7.3 Lubricating oil systems

7.3.1 Lubricating oil arrangements are to comply with the requirements of *Pt 15, Ch 3 Machinery Piping Systems*.

7.3.2 Where the lubricating oil for main propelling gas turbines is circulated under pressure, provision is to be made for the efficient filtration of the oil. The filters are to be capable of being cleaned without stopping the turbine or reducing the supply of filtered oil to the turbine.

7.4 Cooling systems

7.4.1 Cooling water arrangements are to comply with the requirements of *Pt 15, Ch 3 Machinery Piping Systems*, as applicable.

7.5 Inlet and exhaust systems

7.5.1 The air-inlet system is to be designed to minimise the ingestion of harmful particles. Icing up of air intakes is to be prevented.

7.5.2 Means for preventing the accumulation of salt deposits in the compressors and turbines, e.g. water washing, are to be provided.

7.5.3 The arrangement of the exhaust system is to be such as to prevent exhaust gases being drawn into manned spaces, air conditioning systems and air intakes. They should not discharge into air cushion intakes.

7.5.4 Where the exhaust is led overboard near the waterline, means are to be provided to prevent water from being siphoned back to the turbine. Where the exhaust is cooled by water spray, the exhaust pipes are to be self draining overboard. Erosion/ corrosion resistant shut off flaps or other devices are to be fitted on the hull side shell or pipe end and acceptable arrangements made to prevent water flooding the space.

7.5.5 Where two or more turbines have a common exhaust, an isolating device is to be provided in each exhaust pipe.

7.5.6 The exhaust system is to be arranged so that hot exhaust gases are directed away from areas to which personnel have access, either on board or in the vicinity of where the craft is berthed.

Section 8
Control and monitoring

8.1 General

8.1.1 Control engineering systems are to comply with the requirements of *Pt 16 Control and Electrical Engineering*.

8.2 Overspeed protective devices

8.2.1 An overspeed protective device is to be provided for each shaft of main and auxiliary turbines to automatically shut off the fuel, near the burners, to prevent a dangerous overspeed condition of the shaft, unless it can be established that such a condition cannot arise.

8.2.2 The overspeed device is to be set to operate before the speed of the line exceeds the rated maximum speed by 10 per cent. For auxiliary turbines driving electric generators this setting may be increased to 15 per cent.

8.3 Speed governors

8.3.1 Where a main propulsion installation incorporates a reverse gear, electric transmission or controllable (reversible) pitch propeller, a speed governor, independent of the overspeed protective device, is to be fitted and is to be capable of controlling the speed of the unloaded power turbine without bringing the overspeed protective device into action.

8.3.2 Where an auxiliary turbine is intended for driving an electric generator, a speed governor, independent of the overspeed protective device, is to be fitted which, with fixed setting, is to control the speed within 10 per cent momentary variation and five per cent permanent variation when full load is suddenly taken off or put on. The permanent speed variations of a.c. machines intended for parallel operations are to be equal within a tolerance of ±0,5 per cent.

8.4 Lubricating oil failure

8.4.1 Main turbines are to have an arrangement whereby fuel is automatically shut off, near the burners, in the event of failure of the lubrication system.

8.5 Indication of temperature

8.5.1 Means are to be provided for indicating the temperature of power turbine exhaust gases.

8.6 Automatic and remote controls

8.6.1 Where gas turbines are fitted with automatic or remote controls so that under normal operating conditions they do not require any manual intervention by the operators, they are to be provided with the alarm and safety arrangements required by *Pt 10, Ch 2, 8.6 Automatic and remote controls 8.6.2* and *Table 2.8.1 Alarms and safeguards* as appropriate. Alternative arrangements which provide equivalent safeguards will be considered.

8.6.2 The following turbine services are to be fitted with automatic temperature controls so as to maintain steady state conditions throughout the normal operating range of the turbine:

(a) Lubricating oil supply.
(b) Fuel oil supply, *see also Pt 10, Ch 2, 8.6 Automatic and remote controls 8.6.3*.
(c) Exhaust gas.

8.6.3 The fuel oil supply may be fitted with an automatic control for viscosity instead of the temperature control required by *Pt 10, Ch 2, 8.6 Automatic and remote controls 8.6.2*.

8.6.4 A means of manually shutting off the fuel in an emergency is to be provided at the manoeuvring station.

Table 2.8.1 Alarms and safeguards

Item	Alarm	Note
Overspeed	High	Automatic shutdown
Lubricating oil pressure for turbine and gearing	1st stage low	Automatic shutdown
	2nd stage low	
Lubricating oil temperature	High	
Lubricating oil filter differential pressure	High	
fuel oil supply pressure	Low	
Fuel oil supply temperature	High	
Bearing temperature	High	
Exhaust gas temperature	1st stage high	
	2nd stage high	Automatic shutdown
Turbine vibration	1st stage high	
	2nd stage high	Automatic shutdown
Rotor axial displacement	High	Automatic shutdown, *see* Note 2
Flame and ignition	Failure	Automatic shutdown
Automatic starting	Failure	Automatic shutdown
Compressor inlet vacuum	1st stage high	
	2nd stage high	Automatic shutdown
Control system	Failure	

Note 1. Automatic or interlocked means are to be provided for clearing all parts of the main gas turbine of the accumulation of liquid fuel or for purging gaseous fuel, before ignition commences on starting or recommences after failure to start.

Note 2. Except for gas turbines with rolling element bearings

■ *Section 9*
Requirements for craft which are not required to comply with the HSC Code

9.1 General

9.1.1 The requirements of *Pt 10, Ch 2, 1 General requirements* apply to craft which are not required to comply with the HSC Code, unless specifically exempted by the contents of this Section.

9.1.2 The requirements of *Pt 10, Ch 2, 1.4 Inclination of craft 1.4.1* do not apply to yachts or service craft less than 24 m.

9.2 Information and calculations

9.2.1 Gas turbines for craft with a power output not exceeding 110 kW do not have to comply with *Pt 10, Ch 2, 2.1 Plans and information 2.1.2.(c)* and *Pt 10, Ch 2, 2.1 Plans and information 2.1.2.(d)* or *Pt 10, Ch 2, 2.1 Plans and information 2.1.4* inclusive and *Pt 10, Ch 2, 2.1 Plans and information 2.1.9*.

9.3 Starting arrangements

9.3.1 Craft with a Service Group notation of G1 or G2 do not have to comply with *Pt 10, Ch 2, 6.1 Initial starting arrangements 6.1.1*.

9.4 Piping systems

9.4.1 Soft solder is not to be used for attaching pipe fittings forming part of fuel oil systems.

Contents

Section

■ *Section 1* General requirements

1.1 Application

1.1.1 This Chapter is to be read in conjunction with the General Requirements for Machinery in *Pt 9 General Requirements for Machinery*.

1.1.2 The requirements of this Chapter, except where otherwise stated are applicable to electric motor, gas turbine and diesel engine gearing for driving:

(a) Conventional, totally submerged propeller(s)/impeller(s) for main propulsion purposes, for transmitted powers greater than 220 kW.

(b) Auxiliary machinery which is essential for the safety of the craft or for safety of persons on board where the transmitted powers exceed 110 kW.

Note Alternatively calculations using the methods defined in ISO 6336 – *Calculation of load capacity of spur and helical gears* will be considered.

1.1.3 Gear designs for applications other than those specified in *Pt 11, Ch 1, 1.1 Application 1.1.2* will be specially considered.

1.1.4 In any mesh, the terms pinion and wheel refer to the smaller and larger gear respectively.

1.1.5 Bevel gears will be specially considered on the basis of a conversion to equivalent cylindrical gears.

1.1.6 For vibration and alignment requirements, *see Pt 13 Shaft Vibration and Alignment*.

1.2 Power ratings

1.2.1 In this Chapter where the dimensions of any particular components are determined from shaft power, P, in kW, and revolutions per minute, R, the values to be used are those defined in *Pt 9 General Requirements for Machinery*.

1.3 Inclination of craft

1.3.1 Main and auxiliary gear units are to operate satisfactorily under the conditions as shown in *Table 1.4.1 Inclinations*.

Section 2
Particulars to be submitted

2.1 Submission of information

2.1.1 At least three copies of the following plans and information as detailed in *Pt 11, Ch 1, 2.2 Plans* are to be submitted.

2.2 Plans

2.2.1 **Gearing**

(a) Cross sectional views indicating general arrangement.
(b) Detailed plans of elements.

2.2.2 **Shafting and auxiliary systems**

(a) Mass elastic schematic showing gear unit torsional data.
(b) Arrangements plan indicating bearing positions.
(c) Detailed plans indicating scantlings of shafts, couplings and bolting.
(d) Schematic plans of the lubricating oil system, together with pipe material, relief valve and working pressures.
(e) Schematic of the control and electrical system.

2.3 Information

2.3.1 **Gearing:**

(a) Operational power/speed envelope for each pinion.
(b) Number of teeth in each gear.
(c) Reference diameters.
(d) Helix angles at reference diameters.
(e) Normal pitches of teeth at reference diameters.
(f) Tip diameters.
(g) Root diameters.
(h) Face widths and gaps, where applicable.
(i) Pressure angles of teeth (normal or transverse) at reference diameters.
(j) Accuracy grade Q in accordance with ISO 1328 or an equivalent Standard.
(k) Surface texture of tooth flanks and roots.
(l) Minimum backlash.
(m) Centre distance.
(n) Basic rack tooth form.
(o) Protuberance and final machining allowance.
(p) Details of post hobbing processes, if any.
(q) Details of tooth flank corrections, if adopted.
(r) Case depth for surface-hardened teeth.
(s) Shrinkage allowance for shrunk-on rims and hubs.
(t) Type of coupling proposed for oil engine applications.
(u) Details of surface treatment.
(v) Additional measures, not covered by the Rules, taken during manufacture of the gear elements, to improve the load capacity of the gear teeth.
(w) Calculations for short term high power operation, where applicable, *see Pt 9 General Requirements for Machinery*.
(x) Failure mode effects analysis as required by *Pt 9 General Requirements for Machinery*.
(y) Specifications for carbon-manganese and alloy steel forging materials of pinions, pinion sleeves, wheel rims, gear wheels, couplings, bolting and all transmission shafting, giving chemical composition, heat treatment and mechanical properties.

2.3.2 **Shafting and auxiliary systems:**

(a) Details of clutch units, where fitted.
(b) Details of alarms and control systems, where fitted.
(c) Schematic plans of the lubricating oil system, together with pipe material, relief valve and working pressures.

■ *Section 3* Materials

3.1 Requirements and specifications

3.1.1 Components for gearboxes are to be in accordance with the *Rules for the Manufacture, Testing and Certification of Materials, July 2021* (hereinafter referred to as the Rules for Materials).

3.1.2 Manufacturer's certificates for forgings may be accepted where the transmitted power does not exceed 220 kW, *see Ch 1, 3.1 General 3.1.3.(b)* of the Rules for Materials.

3.1.3 In the selection of materials for pinions and wheels, consideration is to be given to their compatibility in operation. Except in the case of low reduction ratios, for gears of through-hardened steels, provision is also to be made for a hardness differential between pinion teeth and wheel teeth. For this purpose, the specified minimum tensile strength of the wheel rim material is not to be more than 85 per cent of that of the pinion.

3.1.4 Gear wheel and rim forgings with a specified minimum tensile strength not in excess of 760 N/mm^2 may be made in carbon-manganese steel. Gear wheel or rim forgings where the specified minimum tensile strength is in excess of 760 N/mm^2, and all pinion or pinion sleeve forgings are to be made in a suitable alloy steel.

3.1.5 Forgings for couplings, quill shafts and gear wheel shafts are to comply with the requirements of *Pt 11, Ch 2 Shafting Systems*.

■ *Section 4* Design of gearing

4.1 Symbols

4.1.1 For the purposes of this Chapter the following symbols apply:

a = centre distance, in mm

b = face width, in mm

= Note: unless otherwise specified, b is to be taken as the lesser value of b_1 or b_2.

= In the case of double helical gears $b = 2b_B$ where b_B is the width of one helix.

d = reference diameter, in mm

d_a = tip diameter, in mm

d_{an} = virtual tip diameter, in mm

d_b = base diameter, in mm

d_{bn} = virtual base diameter, in mm

d_{en} = virtual diameter to the highest point of single tooth pair contact, in mm

d_f = root diameter, in mm

d_{fn} = virtual root diameter, in mm

d_n = virtual reference diameter, in mm

d_s = shrink diameter, in mm

d_w = pitch circle diameter, in mm

f_{ma} = tooth flank misalignment due to manufacturing errors, in µm

f_{pb} = maximum base pitch deviation of wheel, in µm

f_{Sh} = tooth flank misalignment due to wheel and pinion deflections, in µm

f_{Sho} = intermediary factor for the determination of f_{Sh}

g_α = length of line of action for external gears, in mm:

$$= 0,5\sqrt{\left(d^2_{a1} - d^2_{b1}\right)} + 0,5\sqrt{\left(d^2_{a2} - d^2_{b2}\right)} - asin\,\alpha_{tw}$$

= for internal gears:

$$= 0,5\sqrt{\left(d^2_{a1} - d^2_{b1}\right)} - 0,5\sqrt{\left(d^2_{a2} - d^2_{b2}\right)} + asin\,\alpha_{tw}$$

h = total depth of tooth, in mm

h_{ao} = basic rack addendum of tool, in mm

h_F = bending moment arm for root stress, in mm

h_w = sum of actual tooth addenda of pinion and wheel, in mm

m_n = normal module, in mm

n = rev/min of pinion

q = machining allowances, in mm

q_s = notch parameter

q' = intermediary factor for the determination of C_γ

u = $\text{gear ratio} = \dfrac{\text{Number of teeth in wheel}}{\text{Number of teeth in pinion}} \geq 1$

v = linear speed at pitch circle, in m/s

x = addendum modification coefficient

y_α = running in allowance, in µm

y_β = running in allowance, in µm

z = number of teeth

z_n = virtual number of teeth = $\dfrac{z}{cos^2\,\beta_o cos\,\beta}$

C_γ = tooth mesh stiffness (mean total mesh stiffness per unit face width), in N/mm µm

F_t = nominal tangential tooth load, in N

$$= \frac{P}{nd} 19,098 \times 10^6$$

F_β = total tooth alignment deviation (maximum value specified), in µm

$F_{\beta x}$ = actual longitudinal tooth flank deviation before running in, in µm

$F_{\beta y}$ = actual longitudinal tooth flank deviation after running in, in µm

Hv = Vickers hardness number

K_A = application factor

$K_{F\alpha}$ = transverse load distribution factor

$K_{F\beta}$ = longitudinal load distribution factor

$K_{H\alpha}$ = transverse load distribution factor

$K_{H\beta}$ = longitudinal load distribution factor

K_v = dynamic factor

$K_{v\alpha}$ = dynamic factor for spur gears

$K_{v\beta}$ = dynamic factor for helical gears

K_γ = load sharing factor

P = transmitted power, in kW

P_r = radial pressure at shrinkage surface, in N/mm^2

P_{ro} = protuberance of tool, in mm

R_a = surface roughness – arithmetical mean deviation (C.L.A.) as determined by an instrument having a minimum wavelength cut-off of 0,8 mm and for a sampling length of 2,5 mm, in µm

S_{pr} = residual undercut left by protuberance in mm

$S_{F\,min}$ = minimum factor of safety for bending stress

S_{Fn} = tooth root chord in the critical section, in mm

$S_{H\,min}$ = minimum factor of safety for Hertzian contact stress

S_R = rim thickness of gears, in mm

Y_B = rim thickness factor

Y_D = design factor

Y_{DT} = deep tooth factor

Y_F = tooth form factor

$Y_{R\,rel\,T}$ = relative surface finish factor

Y_S = stress correction factor

Y_{ST} = stress correction factor (relevant to the dimensions of the standard reference test gears)

Y_x = size factor

Y_β = helix angle factor

$Y_{\delta\ rel\ T}$ = relative notch sensitivity factor

Z_E = material elasticity factor

Z_H = zone factor

Z_R = surface finish factor

Z_V = velocity factor

Z_X = size factor

Z_β = helix angle factor

Z_ϵ = contact ratio factor

α_{en} = pressure angle at the highest point of single tooth contact, in degrees

α_n = normal pressure angle at reference diameter, in degrees

α_t = transverse pressure angle at reference diameter, in degrees

α_{tw} = transverse pressure angle at pitch circle diameter, in degrees

$\alpha_{F\ en}$ = angle for application of load at the highest point of single tooth contact, in degrees

β = helix angle at reference diameter, in degrees

β_b = helix angle at base diameter, in degrees

γ = intermediary factor for the determination of f_{Sh}

ϵ_α = transverse contact ratio

$$= \frac{g_\alpha \cos\beta}{\pi m_n \cos\alpha_t}$$

$\epsilon_{\alpha n}$ = virtual transverse contact ratio

ϵ_β = overlap ratio

$$= \frac{b \sin\beta}{\pi m_n}$$

ϵ_γ = total contact ratio

ρ_{ao} = tip radius of tool, in mm

ρ_c = relative radius of curvature at pitch point, in mm

$$= \frac{a \sin \alpha_{tw} u}{\cos \beta_b (1+u)^2}$$

ρ_F = tooth root fillet radius at the contact of the 30° tangent, in mm

σ_y = yield or 0,2 per cent proof stress, in N/mm^2

σ_B = ultimate tensile strength, in N/mm^2

σ_F = bending stress at tooth root, N/mm^2

$\sigma_{F\,lim}$ = endurance limit for bending stress in N/mm^2

σ_{FP} = allowable bending stress at the tooth root, in N/mm^2

σ_H = Hertzian contact stress at the pitch circle, in N/mm^2

$\sigma_{H\,lim}$ = endurance limit for Hertzian contact stress, in N/mm^2

σ_{HP} = allowable Hertzian contact stress, in N/mm^2

Subscript:

$_1$ = pinion

$_2$ = wheel

$_0$ = tool

Note *a* and *z* are considered positive for both external and internal gearing for the purposes of these calculations.

4.2 Tooth form

4.2.1 The tooth profile in the transverse section is to be of involute shape, and the roots of the teeth are to be formed with smooth fillets of radii not less than 0,25 m_n.

4.2.2 All sharp edges left on the tips and ends of pinion and wheel teeth after hobbing and finishing are to be removed.

4.3 Tooth loading factors

4.3.1 For values of application factor, K_A, *see Table 1.4.1 Values of K_A* .

Table 1.4.1 Values of K_A

Main and auxiliary gears	K_A
Main propulsion - electric motor or gas turbine, reduction gears	1,15
Main propulsion - diesel engine reduction gears:	
Hydraulic coupling or equivalent on input	1,10
High elastic coupling on input	1,30
Other coupling	1,50
Auxiliary Gears:	
Electric, gas turbine and diesel engine drives with hydraulic coupling or equivalent on input	1,00
Diesel engine drives with high elastic coupling on input	1,20
Diesel engine drives with other couplings	1,40

4.3.2 Load sharing factor, K_γ. When a gear drives two or more mating gears where the total transmitted load is not evenly distributed between the individual meshes, a factor, K_γ, is to be applied. K_γ is defined as the ratio between the maximum load through an actual path and the evenly shared load. This is to be determined by measurements. Where a value cannot be determined in such a way, the values in *Table 1.4.2 Values of* K_y may be considered:

Table 1.4.2 Values of K_y

	K_y
Spur Gear	1,0
Epicyclic Gears	
Up to 3 planetary gears	1,0
4 planetary gears	1,2
5 planetary gears	1,3
6 planetary gears and over	1,4

4.3.3 **Dynamic factor, K_V**, is to be calculated as follows when all the following conditions are satisfied:

$$\frac{vz_1}{100}\sqrt{\frac{u^2}{1+u^2}} < 10\,\mathrm{m/s}$$

- spur gears ($\beta = 0°$) and helical gears with $\beta \leq 30°$
- pinion with relatively low number of teeth, $z_1 < 50$
- solid disc wheels or heavy steel gear rim

Or this method may also be applied to all types of gears if:

$$\frac{vz_1}{100}\sqrt{\frac{u^2}{1+u^2}} < 3\,\mathrm{m/s}$$

And to helical gears where $\beta > 30°$

(a) For spur gears and for helical gears with $\epsilon_\beta \geq 1$:

$$K_v = 1 + \left(\frac{K_1}{K_A \frac{F_t}{b}} + K_2\right)\frac{vz_1}{100}K_3\sqrt{\frac{u^2}{1+u^2}}$$

Where $K_A F_t/b$ is less than 100 N/mm, the value 100 N/mm is to be used. Numerical values for the factor K_1 are to be as specified in the *Table 1.4.3 Values of* K_1

Table 1.4.3 Values of K_1

	K_1 ISO accuracy Grade					
	3	**4**	**5**	**6**	**7**	**8**
Spur Gears	2,1	3,9	7,5	14,9	26,8	39,1
Helical Gears	1,9	3,5	6,7	13,3	23,9	34,8

(a) For all accuracy grades the factor K_2 is to be in accordance with the following:

- for spur gears $K_2 = 0{,}0193$
- for helical gears $K_2 = 0{,}0087$

Factor K_3 is to be in accordance with the following:

If $\dfrac{vz_1}{100}\sqrt{\dfrac{u^2}{1+u^2}} \le 0,2$ then $K_3 = 2,0$

If $\dfrac{vz_1}{100}\sqrt{\dfrac{u^2}{1+u^2}} \le 0,2$ then $K_3 = 2,071 - 0,357\dfrac{vz_1}{100}\sqrt{\dfrac{u^2}{1+u^2}}$

(b) For helical gears with overlap ratio $\epsilon_\beta < 1$, the value K_v is to be determined by linear interpolation between values determined for spur gears ($K_{v\alpha}$) and helical gears ($K_{v\beta}$) in accordance with:

$$K_v = K_{va} - \epsilon_\beta \left(K_{v\alpha} - K_{v\beta}\right)$$

$K_{v\alpha}$ is the K_v value for spur gears, in accordance with *Pt 11, Ch 1, 4.3 Tooth loading factors 4.3.3*

$K_{v\beta}$ is the K_v value for helical gears, in accordance with *Pt 11, Ch 1, 4.3 Tooth loading factors 4.3.4.(b)*

4.3.5 **Longitudinal load distribution factors, $K_{H\beta}$ and $K_{F\beta}$:**

$$K_{H\beta} = 1 + \frac{bF_{\beta y}C\gamma}{2F_t K_A K_\gamma K_v}$$

Calculated values of $K_{H\beta} > 2$ are to be reduced by improved accuracy and helix correction as necessary:

where

$F_{\beta y}$ = $F_{\beta x} - y_\beta$ and

$F_{\beta x}$ = $1{,}33 f_{Sh} + f_{ma}$

f_{ma} = $\frac{2}{3} F_\beta$ at the design stage, or

f_{ma} = $\frac{1}{3} F_\beta$ where helix correction has been applied

f_{Sh} = $F_{Sho}\dfrac{F_t K_A K_\gamma K_v}{b}$

where

F_{Sho} = $23\gamma 10^{-3}$ µm mm/N for gears without helix correction or crowning and without end relief, or

= $12\gamma 10^{-3}$ µm mm/N for gears without helix correction but with crowning, *See* Note 1

= $16\gamma 10^{-3}$ µm mm/N for gears without helix correction but with end relief, where

γ = $\left(\dfrac{b}{d_1}\right)^2$ for single helical and spur gears

= $3\left(\dfrac{b}{2d_1}\right)^2$ for double helical gears

The following minimum values are applicable, these also being the values where helix correction has been applied:

f_{Sho} = 10×10^{-3} µm mm/N for helical gears, or

= 5×10^{-3} µm mm/N for spur gears

For through-hardened steels and surface hardened steels running on through-hardened steels:

y_β = $\dfrac{320}{\sigma_{H\,lim}} F_{\beta x}$ up to an upper limit value of

y_β = $\dfrac{12800}{\sigma_{H\,lim}}$ m, and

For surface hardened steels, when

y_{β} = $0{,}15F_{\beta x}$ up to an upper limit value of

y_{β} = 6 µm

$F_{F\beta}$ = $K_{H\beta}n$

where

=

$$n = \frac{\left(\frac{b}{h}\right)^2}{1 + \frac{b}{h} + \left(\frac{b}{h}\right)^2}$$

Note 1. $\frac{b}{h}$ is to be taken as the smaller of $\frac{b_1}{h_1}$ *or* $\frac{b_2}{h_2}$

Note 2. For double helical gears $\frac{b}{2}$ is to be substituted for *b* in the equation for *n*.

4.3.6 **Transverse load distribution factors, $K_{H\alpha}$ and $K_{F\alpha}$**

(a) Values $K_{H\alpha}$ and $K_{F\alpha}$ for gears with total contact ratio $\epsilon_{\gamma} \le 2$

$$K_{H\alpha} = K_{F\alpha} = \frac{\varepsilon_{\gamma}}{2}\left(0,9 + \frac{0,4C_{\gamma}\left(f_{pb} - y_{\alpha}\right)b}{F_t K_A K_{\gamma} K_v K_{H\beta}}\right)$$

(b) Values $K_{H\alpha}$ and $K_{F\alpha}$ for gears with total contact ratio $\epsilon_{\gamma} > 2$

$$K_{H\alpha} = K_{F\alpha} = 0,9 + 0,4\sqrt{\frac{2\left(\varepsilon_{\gamma} - 1\right)}{\varepsilon_{\gamma}}}\left(\frac{C_{\gamma}\left(f_{pb} - y_{\alpha}\right)b}{F_t K_A K_{\gamma} K_v K_{H\beta}}\right), \text{ but}$$

Limiting conditions for $K_{H\alpha}$:

If $K_{H\alpha} > \frac{\varepsilon_{\gamma}}{\varepsilon_a Z_{\varepsilon}^2}$ when calculated in accordance with (a) or (b), then $K_{H\alpha} = \frac{\varepsilon_{\gamma}}{\varepsilon_a Z_{\varepsilon}^2}$

If $K_{H\alpha} < 1$ when calculated in accordance with (a) or (b), then $K_{H\alpha} = 1$

Limiting conditions for $K_{F\alpha}$:

If $K_{F\alpha} > \frac{\varepsilon_{\gamma}}{0,25\,\varepsilon_{\alpha} + 0,75}$ when calculated in accordance with (a) or (b), then $K_{F\alpha} = \frac{\varepsilon_{\gamma}}{0,25\,\varepsilon_{a} + 0,75}$

If $K_{F\alpha} < 1$ when calculated in accordance with (a) or (b), then $K_{F\alpha} = 1$

When tip relief is applied f_{pb} is to be half of the maximum specified value:

$y_{\alpha} = \frac{160}{\sigma_{H\lim}}$ = for through-hardened steels, when

f_{pb}

$y_{\alpha} \le \frac{6400}{\sigma_{H\lim}}$ = and

μ

m

y_{α} = $0{,}075\, f_{pb}$ for surface hardened steels, when

$\boldsymbol{y_{\alpha}} \le 3$ µm

When pinion and wheel are manufactured from different materials:

$$y_{\alpha} = \frac{y_{\alpha 1} + y_{\alpha 2}}{2}$$

Note Tip relief is to take the form of either tip and root relief on the pinion, or tip relief on pinion and wheel.

4.3.7 **Tooth mesh stiffness, C_{γ}:**

$$C_{\gamma} = \frac{0,8}{q^1} cos\,\beta \left(0,75\,\varepsilon_{\alpha} + 0,25\right) \text{ N/mm}\,\mu\,\text{m}$$

where

$$= \quad q' = 0,04723 + \frac{0,1551}{z_{n1}} + \frac{0,25791}{z_{n2}} - 0,00635x_1$$
$$- \frac{0,11654x_1}{z_{n1}} - 0,00193x_2 - \frac{0,24188x_2}{z_{n2}}$$
$$+0,00529x_1^{\;2} + 0,00182x_2^{\;2}$$

For internal gears $Z_{n2} = \infty$

Other calculation methods for C_{γ} will be specially considered.

4.4 Tooth loading for surface stress

4.4.1 The Hertzian contact stress, σ_H, at the pitch circle is not to exceed the allowable Hertzian contact stress, σ_{HP}.

$$\sigma = Z_H Z_E Z_{\varepsilon} Z_{\beta} \sqrt{\frac{F_t(u+1)}{d_1 bu} K_A K_{\gamma} K_v K_{H\beta} K_{Ha}}$$

and

$$\sigma_{HP} = \frac{\sigma_{H\lim} Z_R Z_V Z_X}{S_{H\min}}$$ for the pinion/wheel combination

where

$$Z_H = \sqrt{\frac{2cos\,\beta_b}{cos^2\,\alpha_t\,tan\,\alpha_{tw}}}$$
$$Z_E = 189,8 \; for\ steel$$

Z_{ϵ}, contact ratio factor is to be calculated as follows:

for helical gears:

$$Z_{\varepsilon} = \sqrt{\frac{4-\varepsilon_{\alpha}}{3}\left(1-\varepsilon_{\beta}\right) + \frac{\varepsilon_{\beta}}{\varepsilon_{\alpha}}} \; for\ \varepsilon_{\beta} < 1 \; and$$

$$Z_{\varepsilon} = \sqrt{\frac{1}{\varepsilon_{\alpha}}} \; for\ \varepsilon_{\beta} \geq 1$$

for spur gears

$$Z_{\varepsilon} = \sqrt{\frac{4-\varepsilon_{\alpha}}{3}}$$
$$Z_{\beta} = \sqrt{\frac{1}{cos\,\beta}}$$
$$Z_R = \left(\frac{3}{R_{Z10}}\right)^{C_{ZR}}$$

where:

$$R_Z = \frac{R_{Z1} + R_{Z2}}{2}$$

The peak to valley roughness determined for the pinion R_{Z1} and for the wheel R_{Z2} are mean values for the peak to valley roughness R_z measured on several tooth flanks.

$$R_{Z10} = R_Z \sqrt[3]{\frac{10}{\rho_{red}}}$$

relative radius of curvature:

$$\rho_{red} = \frac{\rho_1 \cdot \rho_2}{\rho_1 + \rho_2}$$

where:

$$\rho_{1,2} = 0,5 \cdot d_{b1,2} \cdot \tan\alpha_{tw}$$

For internal gears, d_b has a negative sign.

If R_a, the surface roughness of the tooth flanks is given then the following approximation may be applied:

$$R_a = \frac{R_Z}{6}$$

C_{ZR} is to be taken from *Table 1.4.4 Values of C $_{ZR}$* .

$$Z_v = 0,88 + 0,23\left(0,8 + \frac{32}{v}\right)^{-0,5}$$

For values of Z_x, *see Table 1.4.5 Values of Z_x*

$\sigma_{H\,lim}$, *see Table 1.4.6 Values of endurance limit for Hertzian contact stress, $\sigma_{H\,lim}$*

$S_{H\,min}$, *see Table 1.4.7 Factors of safety*

Table 1.4.4 Values of *C* $_{ZR}$

$\sigma_{H\,lim}$	C_{ZR}
$\sigma_{H\,lim}$ < 850 N/mm^2	0,150
850 N/mm^2 ≤ $\sigma_{H\,lim}$ ≤ 1200 N/mm^2	=0,32-0,0002·$\sigma_{H\,lim}$
$\sigma_{H\,lim}$ >1200 N/mm^2	0,080

Table 1.4.5 Values of Z_x

Pinion heat treatment		Z_x
Carburised and induction-hardened	$m_n \leq 10$	1,00
	$10 < m_n < 30$	1,05 - 0,005m_n
	$30 \leq m_n$	0,9
Nitrided	$m_n < 7,5$	1,00
	$7,5 < m_n < 30$	1,08 - 0,005m_n
	$30 \leq m_n$	0,75
Through-hardened	All modules	1,00

Table 1.4.6 Values of endurance limit for Hertzian contact stress, σ H lim

Heat treatment		
Pinion	Wheel	
Through-hardened	Through-hardened	$0,46\sigma_{B2} + 255$
Surface-hardened	Through-hardened	$0,42\sigma_{B2} + 415$
Carburised, nitrided or induction-hardened	Soft bath nitrided (tufftrided)	1000
Carburised, nitrided or induction-hardened	Induction-hardened	$0,88HV_2 + 675$
Carburised or nitrided	Nitrided	1300
Carburised	Carburised	1500

Table 1.4.7 Factors of safety

	$S_{H\ min}$	$S_{F\ min}$
Main propulsion gears	1,40	1,80
Auxiliary gears	1,15	1,40

4.5 Tooth loading for bending stress

4.5.1 The bending stress at the tooth root, σ_F is not to exceed the allowable tooth root bending stress σ_{FP}:

$$\sigma_F = \frac{F_t}{bm_n} Y_F Y_S Y_\beta Y_B Y_{DT} K_A K_\gamma K_v K_{F\alpha} K_{F\beta} \quad \text{N/mm}^2$$

$$\sigma_{FP} = \frac{\sigma_{F\ lim} Y_{ST} Y_{d\ rel\ T} Y_{R\ rel\ T} Y_x}{S_{F\ min} Y_D} \quad \text{N/mm}^2$$

Note If b_1 and b_2 are not equal to the load bearing width of the wider face taken is not to exceed that of the smaller plus $2m_n$.

For values of $S_{F\ min}$, *see Table 1.4.7 Factors of safety*

= $\sigma_{F\ lim}$, *see Table 1.4.8 Values of endurance limit for bending stress, $\sigma_{F\ lim}$*

Stress correction factor Y_{ST} = 2.

4.5.2 **Tooth form factor, Y_F:**

$$Y_F = \frac{6\frac{h_F}{m_n}\cos\alpha_{Fen}}{\left(\frac{S_{Fn}}{m_n}\right)^2 \cos\alpha_n}$$

where h_F, α_{Fen} and S_{Fn} are shown in *Figure 1.4.1 Normal tooth section*.

$$\frac{S_{\text{Fn}}}{m_{\text{n}}} = z_{\text{n}} sin\left(\frac{\pi}{3} - \upsilon\right) + \sqrt{3}\left(\frac{G}{cos\,\upsilon} - \frac{\rho_{\text{ao}}}{m_{\text{n}}}\right)$$

where

$$\upsilon = \frac{2G}{z_{\text{n}}} tan\,\upsilon - H$$

$$G = \frac{\rho_{\text{ao}}}{m_{\text{n}}} - \frac{h_{\text{ao}}}{m_{\text{n}}} + x$$

$$H = \frac{2}{z_{\text{n}}}\left(\frac{\pi}{2} - \frac{E}{m_{\text{n}}}\right) - \frac{\pi}{3}$$

$$E = \frac{\pi}{4} m_{\text{n}} - h_{\text{ao}} tan\,\alpha_{\text{n}} + \frac{S_{\text{pr}}}{cos\,\alpha_{\text{n}}} - \left(1 - sin\,\alpha_{\text{n}}\right)\frac{\rho_{\text{ao}}}{cos\,\alpha_{\text{n}}}$$

E, h_{ao}, α_{n}, S_{pr} and ρ_{ao} are shown in *Figure 1.4.2 External tooth forms*.

$$\frac{\rho_{\text{F}}}{m_{\text{n}}} = \frac{\rho_{\text{ao}}}{m_{\text{n}}} + \frac{2G^2}{cos\,u\left(z_{\text{n}} cos^2\,\upsilon - 2G\right)}$$

$$d_{\text{en}} = \frac{2z}{|z|}\left\{\left[\sqrt{\left(\frac{d_{\text{n}}}{2}\right)^2 - \left(\frac{d_{\text{bn}}}{2}\right)^2} - \frac{\pi\, d\, cos\,\beta\, cos\,\alpha_n}{|z|}\left(\varepsilon_{\alpha\text{n}} - 1\right)\right]^2 + \left(\frac{d_{\text{bn}}}{2}\right)^2\right\}^{\frac{1}{2}}$$

where

$d_{\text{an}} = d_{\text{n}} + d_{\text{a}} - d$

$=$

$$d_{\text{n}} = \frac{d}{cos^2\,\beta_{\text{b}}}$$

$$d_{\text{bn}} = d_{\text{n}} cos\,\alpha_{\text{n}}$$

$$\varepsilon_{\alpha\text{n}} = \frac{\varepsilon_{\alpha}}{cos^2\,\beta_{\text{b}}}$$

$$\gamma_{\text{e}} = \frac{\frac{z\,\pi}{2} + 2x tan\,\alpha_{\text{n}}}{z_{\text{n}}} + inv.\,\alpha_{\text{n}} - inv.\,\alpha_{\text{en}}$$

where

$$\alpha_{\text{en}} = arc\,cos\frac{d_{bn}}{d_{en}}$$

$$= \frac{h_{\text{F}}}{m_{\text{n}}} = \frac{1}{2}\left[\left(cos\,\gamma_{\text{e}} - sin\,\gamma_{\text{e}} tan\,\alpha_{F\,\text{en}}\right)\frac{d_{\text{en}}}{m_{\text{n}}} - z_{\text{n}} cos\left(\frac{\pi}{3} - v\right)\frac{G}{cos\,\upsilon} + \frac{\rho_{\text{ao}}}{m_{\text{n}}}\right]$$

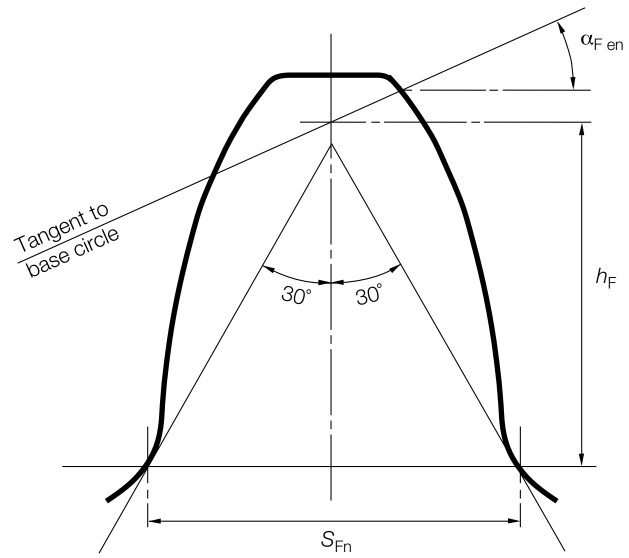
where

$\alpha_{\text{F en}} = \alpha_{\text{en}} - \gamma_{\text{e}}$

Table 1.4.8 Values of endurance limit for bending stress, $\sigma_{\text{F lim}}$

Heat treatment	$\sigma_{\text{F lim}}$ N/mm^2
Through-hardened carbon steel	0,09σ_{B} + 150
Through-hardened alloy steel	0,1σ_{B} + 185
Soft bath nitrided (Tufftrided)	330
Induction hardened	0,35 *HV* + 125
Gas nitrided	390

Carburised A	450
Carburised B	410
Note 1. A is applicable for Cr Ni Mo carburising steels.	
Note 2. B is applicable for other carburising steels.	



NOTE
For helical gears the normal section is taken with the virtual number of teeth

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Figure 1.4.1 Normal tooth section

4.5.3 For internal tooth forms the form factor is calculated, as an approximation, for a substitute gear rack with the form of the basic rack in the normal section, but having the same tooth depth as the internal gear:

$$\frac{S_{\text{Fn2}}}{m_{\text{n}}} = 2\left[\frac{\pi}{4} + tan\ \alpha\left(\frac{h_{\text{ao2}} - \rho_{\text{ ao2}}}{m_{\text{n}}}\right) + \left(\frac{\rho_{\text{ ao2}} - S_{\text{pr}}}{m_{\text{n}}}\right) - \frac{\rho_{\text{ ao2}}}{m_{\text{n}}} cos\frac{\pi}{6}\right],\ \ and$$

$$\frac{h_{\text{F2}}}{m_{\text{n}}} = \frac{d_{\text{en2}} - d_{\text{fn2}}}{2\text{m}_{\text{n}}} - \left[\frac{\pi}{4} + \left(\frac{h_{\text{ao2}}}{m_{\text{n}}} - \frac{d_{\text{en2}} - d_{\text{fn2}}}{2m_2}\right) tan\ \alpha_{\text{ n}}\right] tan\ \alpha_{\ n} - \frac{\rho\ ao2}{m_{\text{n}}}\left(1 - sin\frac{\pi}{6}\right)$$

where $\alpha_{F\,en}$ is taken as being equal to α_n

$$\rho_{\ F2} = \frac{\rho_{\text{ ao2}}}{2}$$

d_{en2} is calculated as d_{en} for external gears, and

$$d_{\text{fn}} = d - d_{\text{f}} - d_{\text{n}}$$

4.5.4 **Stress concentration factor, Y_s**

$$Y_s = (1,2 + 0,13L)q_s^{\left(\frac{1}{1,21 + 2,3/L}\right)}$$

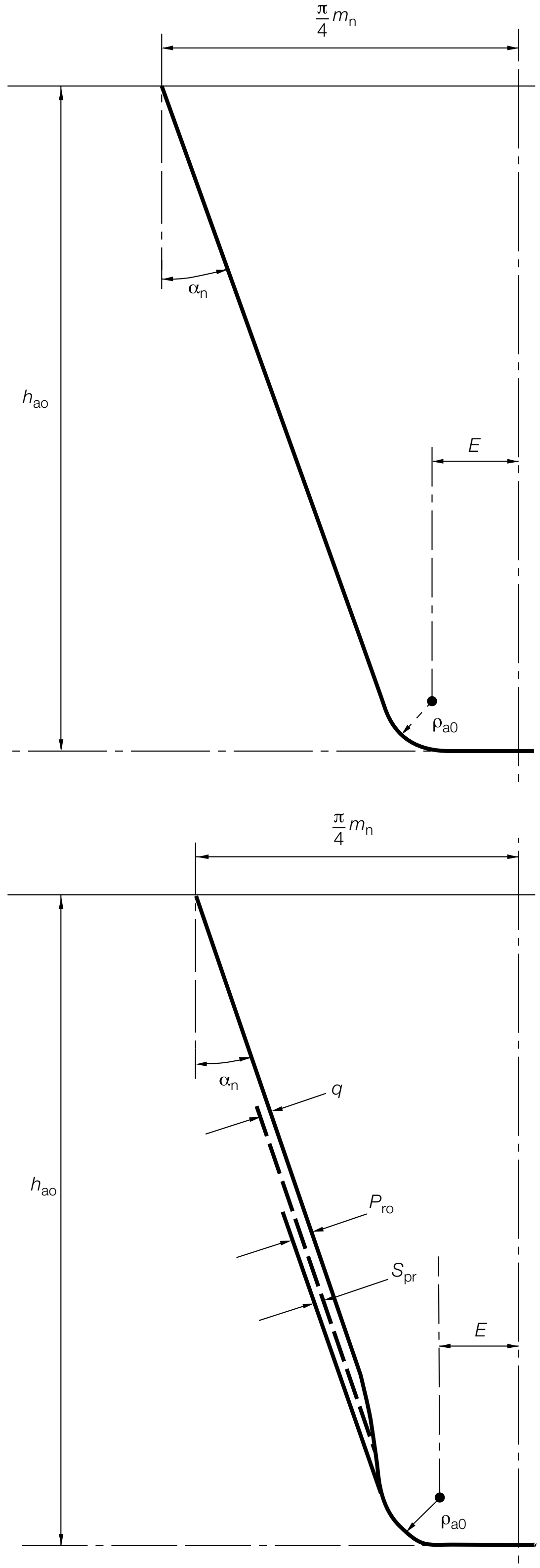
where

$L = \dfrac{S_{Fn}}{h_F}$

$q_s = \dfrac{S_{Fn}}{2\rho_F}$

when $q_s < 1$ the value of Y_s is to be specially considered.

The formula for Y_s is applicable to external gears with $\alpha_n = 20°$ but may be used as an approximation for other pressure angles and internal gears.



NOTES
1. Dimensions shown on rack profile of tooth
2. $S_{pr} = P_{ro} - q$

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Figure 1.4.2 External tooth forms

4.5.5 Helix angle factor Y_{β}

$$Y_{\beta} = 1 - \left(\varepsilon_{\beta} \frac{\beta}{120}\right), if\ \varepsilon_{\beta} > 1\ let\ \varepsilon_{\beta} = 1$$

but

$Y_{b} \geq 1 - 0,25\ 3_{\beta} \geq 0,75$

4.5.6 Rim thickness factor, Y_{B}

Factor Y_{B} is to be determined as follows:

(a) For external gears

If $S_{R}/h \geq 1,2$ then $Y_{B} = 1$

If $0,5 < S_{R}/h < 1,2$ then $Y_{B} = 1,6 \cdot \ln\left(2,242 \frac{h}{S_{R}}\right)$

where

S_{R} = rim thickness of external gears, mm

The case $S_{R}/h \leq 0,5$ is to be avoided.

(b) For internal gears

If $S_{R}/m_{n} \geq 3,5$ then $Y_{B} = 1$

If $1,75 < S_{R}/m_{n} < 3,5$ then $Y_{B} = 1,15 \cdot \ln\left(8,324 \frac{m_{n}}{S_{R}}\right)$

Where

S_{R} = rim thickness of internal gears, mm

The case $S_{R}/m_{n} \leq 1,75$ is to be avoided.

4.5.7 Deep tooth factor Y_{DT}

The deep tooth factor, Y_{DT}, adjusts the root stress to take into account high precision gears and contact ratios within the range of virtual contact ratio $2,05 \leq \epsilon_{\alpha n} \leq 2,5$ where:

$$\varepsilon_{an} = \frac{\varepsilon_{\alpha}}{\cos^{2} \beta_{b}}$$

Factor Y_{DT} is to be determined from *Table 1.4.9 Values of deep tooth factor, Y_{DT}* :

Table 1.4.9 Values of deep tooth factor, Y_{DT}

	Y_{DT}
ISO Accuracy Grade ≤ 4 and $\epsilon_{\alpha n} > 2,5$	0,7
ISO Accuracy Grade ≤ 4 and $2,05 < \epsilon_{\alpha n} \leq 2,5$	$2,366 - 0,666 \cdot \epsilon_{\alpha n}$
In all other cases	1,0

4.5.8 Relative notch sensitivity factor, $Y_{\delta\ rel\ T}$

$$Y_{\delta\, relT} = \frac{1 + \sqrt{0,2\, \rho'\left(1 + 2q_{s}\right)}}{1 + \sqrt{1,2\, \rho'}}$$

ρ' = slip-layer thickness is to be taken from *Table 1.4.10 Slip-layer thickness, ρ'*

Table 1.4.10 Slip-layer thickness, ρ'

Material		ρ', (mm)
Case hardened steels, flame or induction hardened steels		0,0030
Through-hardened steels, yield point R_e =	500 N/mm^2	0,0281
	600 N/mm^2	0,0194
	800 N/mm^2	0,0064
	1000 N/mm^2	0,0014
Nitrided steels		0,1005
Note The given values of ρ' can be interpolated for values of R_e not stated above		

4.5.9 **Relative surface finish factor, $Y_{R\ rel\ T}$**

$Y_{R\ rel\ T}$ = 1,674 – 0,529 $(6R_a + 1)^{0,1}$ for through-hardened, carburised and induction hardened steels, and

= 4,299 – 3,259 $(6R_a + 1)^{0,005}$ for nitrided steels.

4.5.10 **Size factor, Y_x**

Y_x = 1,00, when $m_n \leq 5$

= 1,03 – 0,006m_n for through-hardened steels

= 0,85, when $m_n \geq 30$

= 1,05 – 0,01 m_n for surface-hardened steels

= 0,80, when $m_n \geq 25$.

4.5.11 **Design factor, Y_D**

Y_D = 0,83 for gears treated with a controlled shot peening process

= 1,5 for idler gears

= 1,25 for shrunk on gears, or

$$= 1 + \frac{0,2 d_s^2 d P_r b}{F_t \sigma_{F\ lim} \left(d_f^2 - d_s^2\right)}, \text{ otherwise}$$

= 1,00 or any combination of the above — e.g. Y_D= (0,83 × 1,5) for an idler gear treated with a controlled shot peening process.

4.6 Factors of safety

4.6.1 Factors of safety are shown in *Table 1.4.7 Factors of safety*.

4.7 Design of enclosed gear shafting

4.7.1 The following symbols apply:

P in kW and *R* in rpm, *see Pt 11, Ch 1, 1.2 Power ratings 1.2.1*.

L = span between shaft bearing centres, in mm

σ_n = normal pressure angle at the gear reference diameter, in degrees

β = helix angle at the gear reference diameter, in degrees

d_w = pitch circle diameter of the gear teeth, in mm

σ_u = specified minimum tensile strength of the shaft material, in N/mm^2

Note Numerical value used for σ_u is not to exceed 800 N/mm^2 for gear and thrust shafts and 1100 N/mm^2 for quill shafts.

4.7.2 This sub-Section is applicable to the main and ancillary transmission shafting, enclosed within the gearcase.

4.7.3 The diameter of the enclosed gear shafting adjacent to the pinion or wheel is to be not less than the greater of d_b or d_t, where:

$$d_b = 365\left(\frac{P\,L}{R d_w S_b}\right)^{\frac{1}{3}}\left(1+\left(\frac{\tan\alpha_n}{\cos\beta}+\frac{\tan\beta\, d_w}{L}\right)^2\right)^{\frac{1}{6}}$$

$$d_t = 365\left(\frac{P}{R S_s}\right)^{\frac{1}{3}}$$

where

S_b = 45 + 0,24 (σ_u — 400) and

S_s = 42 + 0,09 (σ_u — 400).

4.7.4 For the purposes of the above it is assumed that the pinion or wheel is mounted symmetrically spaced between bearings.

4.7.5 Outside a length equal to the required diameter at the pinion or wheel, the diameter may be reduced, if applicable, to that required for d_t.

4.7.6 For bevel gear shafts, where a bearing is located adjacent to the gear section, the diameter of the shaft is to be not less than d_t. Where a bearing is not located adjacent to the gear the diameter of the shaft will be specially considered.

4.7.7 The diameter of quill shaft (not axially constrained and subject only to external torsional loading) is to be not less than given by the following formula:

Diameter of quill shaft =

$$101\sqrt[3]{\frac{P400}{R\,\sigma_u}}\ mm$$

4.7.8 Where a shaft, located within the gearcase, is subject to the main propulsion thrust, the diameter at the collars of the shaft transmitting torque, or in way of the axial bearing where a roller bearing is used as a thrust bearing, is to be not less than 1,1 d_t. For thrust bearings located outside the gearcase *see Pt 11, Ch 2, 2 Particulars to be submitted*.

4.8 Gear wheels

4.8.1 In general, arrangements are to be made so that the interior structure of the wheel may be examined. Alternative proposals will be specially considered.

4.9 External shafting and components

4.9.1 For shafting external to the gearbox and other components ancillaries *see Pt 11, Ch 2 Shafting Systems*.

4.10 Clutch actuation

4.10.1 Where a clutch is fitted in the transmission, normal engagement shall not cause excessive stresses in the transmission or the driven machinery. Inadvertent operation of any clutch is not to produce dangerously high stresses in the transmission or driven machinery.

4.11 Gearcases

4.11.1 Gearcases and their supports are to be designed sufficiently stiff such that misalignment at the mesh due to movements of the external foundations and the thermal effects under all conditions of service do not disturb the overall tooth contact.

4.11.2 Inspection openings are to be provided at the peripheries of gearcases to enable the teeth of pinions and wheels to be readily examined. Where the construction of gearcases is such that sections of the structure cannot be readily be moved for inspection purposes, access openings of adequate size are also to be provided at the ends of the gearcases to permit examination of the structure of the wheels. Their attachment to the shafts is to be capable of being examined by removal of bearing caps or by equivalent means.

4.11.3 For gearcases fabricated by fusion welding the carbon content of the steels should generally not exceed 0,23 per cent. Steels with higher carbon content may be approved subject to satisfactory results from weld procedure tests.

4.11.4 Gearcases are to be stress relieved upon completion of all welding.

4.11.5 Gearcases manufactured from material other than steel will be considered upon full details being submitted.

4.12 Backlash

4.12.1 The normal backlash between any pair of gears should not be less than:

$$\frac{a \cdot \alpha_{\mathrm{n}}}{90\,000} + 0{,}1 \ \text{mm}$$

4.12.2 The normal backlash is not to exceed three times the value calculated in *Pt 11, Ch 1, 4.12 Backlash 4.12.1*.

4.13 Alignment

4.13.1 Reduction gears with sleeve bearings, for main and auxiliary purposes are to be provided with means for checking the internal alignment of the various elements in the gearcases.

4.13.2 In the case of separately mounted reduction gearing for main propulsion, means are to be provided by the gear manufacturer to enable the Surveyors to verify that no distortion of the gearcase has taken place, when chocked and secured to its seating on board the craft.

■ *Section 5*
Piping systems for gearing

5.1 General

5.1.1 Piping systems for gearing are to comply with the general design requirements given in *Pt 15 Piping Systems and Pressure Plant*.

5.1.2 The specific requirements for lubricating/hydraulic oil systems and standby arrangements are given in *Pt 15 Piping Systems and Pressure Plant*

5.1.3 Lubricating oil lines are to be screened, or otherwise suitably protected, to avoid oil spray or oil leakages onto hot surfaces, into machinery air intakes or other sources of ignition. The number of joints in such piping systems should be kept to a minimum. Flexible pipes are to be of an approved type.

5.2 Pumps

5.2.1 Where lubricating oil for the reduction gearing is circulated under pressure, pump standby arrangements are to be provided in accordance with *Pt 15 Piping Systems and Pressure Plant*.

5.3 Filters

5.3.1 Where the lubricating oil for the reduction gearing is circulated under pressure, provision is to be made for the efficient filtration of the oil. The filters are to be capable of being cleaned without stopping the gear set or reducing the supply of filtered oil to the gearing.

Section 6
Control and monitoring

6.1 General

6.1.1 Control engineering systems are to be in accordance with *Pt 16 Control and Electrical Engineering*.

6.1.2 All main and auxiliary gear units, intended for essential services, are to be provided with means of indicating the lubricating oil supply pressure. Audible and visual alarms are to be fitted to give warning of an appreciable reduction in pressure of the lubricating oil supply. These alarms are to be actuated from the outlet side of any restrictions, such as filters, coolers, etc.

6.2 Unattended machinery

6.2.1 Where the machinery is fitted with automatic or remote controls so that under normal operating conditions it does not require any manual intervention by the operators, gear units are to be provided with the alarms and safety arrangements required by *Pt 11, Ch 1, 6.2 Unattended machinery 6.2.2* and *Table 1.6.1 Alarms and safeguards*. The sensors and circuits utilised for the second stage alarm and automatic shut down in *Table 1.6.1 Alarms and safeguards* are to be independent of those required for the first stage alarm.

Table 1.6.1 Alarms and safeguards

Item	Alarm	Note
Lubricating oil sump level	Low	
Lubricating oil inlet pressure*	1st Stage Low	
	2nd Stage Low	Automatic shutdown of engine
Lubricating oil inlet temperature*	High	
Thrust bearing temperature*	High	
Note For transmitted powers of 1500 kW or less, only the items marked * are required.		

6.2.2 Where the gear unit is required to be provided with a standby pump, the standby pump is to start automatically if the discharge pressure from the working pump falls below a predetermined value.

Section 7
Requirements for craft which are not required to comply with the HSC Code

7.1 Details to be submitted

7.1.1 Failure mode effect analysis is not required for craft which do not require to comply with the HSC Code.

7.1.2 Mass elastic schematic showing gear unit torsional data is only required for gears with an input power greater than 500kW, *see Pt 11, Ch 1, 2.2 Plans 2.2.2* and *Pt 13 Shaft Vibration and Alignment*.

7.2 Design of gearing

7.2.1 Where they are not intended for passenger carrying duties, the gearing factors of safety for yachts, service craft less than 24 m and ACVs are to satisfy *Table 1.7.1 Factors of safety*.

Table 1.7.1 Factors of safety

	S_H min	S_F min
Main propulsion gears for yachts, etc. single screw	1,25	1,50
Main propulsion gears for yachts, etc. multiple screw	1,20	1,45

7.3 Piping systems

7.3.1 For service craft less than 24 m and for yachts the requirements of *Pt 11, Ch 1, 5.2 Pumps 5.2.1* and *Pt 11, Ch 1, 5.3 Filters 5.3.1* do not apply. These craft are to have gearing provided with an efficient lubricating oil pump, a cooler where necessary, and a filter arrangement which can be cleaned.

7.4 Control and monitoring

7.4.1 For service craft less than 24 m the alarms required by *Pt 11, Ch 1, 6.2 Unattended machinery 6.2.1* are not required.

Section
Scope

■ *Scope*

The requirements of this Chapter relate, in particular, to formulae for determining the diameters of shafting for main propulsion installations, but requirements for couplings, coupling bolts, keys, keyways, sternbushes and other associated components are also included. The diameters may require to be modified as a result of alignment considerations and vibration characteristics, *see Pt 13 Shaft Vibration and Alignment*, or the inclusion of stress raisers, other than those contained in this Chapter.

Alternative calculation methods for determining the diameters of shafting for main propulsion and their permissible torsional stresses will be considered by LR. Any alternative calculation method is to include all relevant loads on the complete dynamic shafting system under all permissible operating conditions. Consideration is to be given to the dimensions and arrangements of all shaft connections. Moreover, an alternative calculation method is to take into account design criteria for continuous and transient operating loads (dimensioning for fatigue strength) and for peak operating loads (dimensioning for yield strength). The fatigue strength analysis may be carried out separately for different load assumptions, for example as given below.

Shafts complying with the applicable Rules in *Pt 11, Ch 2 Shafting Systems* and *Pt 13 Shaft Vibration and Alignment* satisfy the following:

(a) Low cycle fatigue criterion (typically $<10^4$), i.e. the primary cycles represented by zero to full load and back to zero, including reversing torque, if applicable. This is addressed by the formulae in *Pt 11, Ch 2, 4.2 Intermediate shafts*, *Pt 11, Ch 2, 4.4 Screwshafts and tube shafts* and *Pt 11, Ch 2, 4.5 Hollow shafts*.
(b) High cycle fatigue criterion (typically $>10^7$), i.e. torsional vibration stresses permitted for continuous operation as well as reverse bending stresses and the accumulated fatigue due to torsional vibration when passing through a barred speed range or any other transient condition with associated stresses beyond those permitted for continuous operation. This is addressed by the formulae in *Pt 13, Ch 1, 3.2 Limiting stress in propulsion shafting*. The influence of reverse bending stresses is addressed by the safety margins inherent in the formulae from *Pt 11, Ch 2, 4.2 Intermediate shafts*, *Pt 11, Ch 2, 4.4 Screwshafts and tube shafts* and *Pt 11, Ch 2, 4.5 Hollow shafts*.

■ *Section 1*
General requirements

1.1 Application

1.1.1 This Chapter is to be read in conjunction with the General Requirements for Machinery in *Pt 9 General Requirements for Machinery*.

1.1.2 This Chapter gives the requirements for the dimensions of transmission shafts, couplings, coupling bolts, keys, keyways, sternbushes and other associated components of main propulsion shafting.

1.1.3 The diameters may require to be modified as a result of alignment considerations and vibration characteristics (*see Pt 13 Shaft Vibration and Alignment*), or the inclusion of stress raisers, other than those contained in this Chapter.

1.1.4 For shafting enclosed within an gearbox, *see Pt 11, Ch 1, 4.7 Design of enclosed gear shafting*.

1.1.5 For diesel engine crankshaft and turbine rotor shafting, *see Pt 10 Prime Movers*.

1.2 Power ratings

1.2.1 In this Chapter, the dimensions of main propulsion component are determined from shaft power, *P*, in kW, and revolutions per minute, *R*, and general requirements defined in *Pt 9, Ch 1, 1 General requirements*.

1.2.2 For auxiliary machinery, the maximum continuous shaft power and corresponding revolutions per minute which will be used in service are to be stated.

1.3 Clutches

1.3.1 Clutches for single engine propulsion plants are to be provided with a suitable means for emergency operation in the event of loss of operating fluid systems. Their suitability for short term high power operation is to be demonstrated.

1.4 Safety

1.4.1 Means are to be provided such that in the event of a failure to a shaft or coupling the occupants of the craft are not endangered, either directly or by damaging the craft or its systems. Where necessary, guards may be fitted to achieve compliance with these requirements.

■ *Section 2* Particulars to be submitted

2.1 Plans

2.1.1 At least three copies of the following plans are to be submitted:

- Shafting arrangement.
- Thrust shaft.
- Intermediate shafting.
- Tube shaft, where applicable.
- Screwshaft.
- Screwshaft oil gland.
- Screwshaft protection.
- Sternbush and arrangement in housing.
- Couplings.
- Coupling bolts.
- Flexible coupling.
- Cardan shafts.

2.1.2 The shafting arrangement plan is to indicate the relative position of the main engine(s), flywheel, flexible coupling(s), gearing, thrust block, line shafting and bearing(s), sterntube, `A' bracket and propulsion device, as applicable.

2.2 Calculations and specifications

2.2.1 The following calculations and specifications are to be submitted:

- Calculations, or relevant documentation indicating the suitability of all components for short term high power operation, where applicable.
- Where undertaken as an alternative to the requirements of this Chapter, fatigue endurance calculations of all components according to *Pt 9 General Requirements for Machinery*.
- Vibration analysis and alignment analysis as required by *Pt 13 Shaft Vibration and Alignment*.

- The material specifications, including the minimum specified tensile strength of each shaft and coupling component are to be stated. Where corrosion resistant material not included in *Table 2.4.1 `A' Value for use in unprotected screwshaft formula* is used for unprotected screwshafts the corrosion fatigue strength in sea-water is to be stated together with the chemical composition and mechanical properties.
- Where it is proposed to use composite (non-metallic) shafts, details of materials, resin, lay-up procedure and documentary evidence of fatigue endurance strength.

■ *Section 3* Materials

3.1 Materials for shafts

3.1.1 Components are to be manufactured and tested in accordance with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials, July 2021* (hereinafter referred to as the Rules for Materials).

3.1.2 The specified minimum tensile strength of forgings for shafts is to be selected within the following general limits:

(a) Carbon and carbon-manganese steel – 400 to 760 N/mm^2. *See also Pt 11, Ch 2, 4.4 Screwshafts and tube shafts 4.4.3*.

(b) Alloy steel main propulsion shafting:

  (i) not exposed to seawater – not exceeding 800 N/mm^2,

  (ii) for other forgings - not exceeding 1100 N/mm^2.

3.1.3 Where it is proposed to use alloy steel forgings, particulars of the chemical composition, mechanical properties and heat treatment are to be submitted for approval.

3.1.4 Where shafts may experience vibratory stresses close to the permissible stresses for transient operation, the materials are to have a specified minimum tensile strength of 500 N/mm^2.

3.1.5 Where materials with greater specified or actual tensile strengths than the limitations given above are used, reduced shaft dimensions or higher permissible vibration stresses are not acceptable when derived from the formulae used in sub-Sections *Pt 11, Ch 2, 4.2 Intermediate shafts*, *Pt 11, Ch 2, 4.4 Screwshafts and tube shafts*, *Pt 11, Ch 2, 4.5 Hollow shafts* and *Pt 13, Ch 1, 3.2 Limiting stress in propulsion shafting* unless, for intermediate shafts only, it is verified that the materials exhibit a similar fatigue life to conventional steels through compliance with the requirements in *Pt 11, Ch 2, 7 Approval of alloy steel used for intermediate shaft material*.

3.1.6 Unprotected screwshafts and tubeshafts exposed to sea-water are in general to be manufactured from materials that show improved corrosion resistance in seawater when compared to carbon steel and alloy steels, referred to in *Pt 11, Ch 2, 3.1 Materials for shafts 3.1.1* and *Pt 11, Ch 2, 3.1 Materials for shafts 3.1.3*; examples of some such alloys are indicated in *Table 2.4.1 `A' Value for use in unprotected screwshaft formula* . However, the selection of these alloys should carefully consider the level of corrosion resistance in relation to all the environmental service conditions and operational requirements applicable to the individual vessel.

3.1.7 In the selection of materials for shafts, keys, locking nuts etc. consideration is to be given to their compatibility with the proposed propeller material.

3.1.8 Where shafts are manufactured from composite material the process is to be approved.

■ *Section 4* Design and construction

4.1 Fatigue strength analysis

4.1.1 As an alternative to the following requirements , a fatigue strength analysis of components can be submitted indicating a factor of safety of 1,5 at the design loads, based on a suitable fatigue failure criteria The effects of stress concentrations, material properties and operating environment are to be taken into account.

4.2 Intermediate shafts

4.2.1 The diameter, *d*, of the intermediate shaft is to be not less than:

$$d = Fk\sqrt[3]{\frac{P}{R}\left(\frac{560}{\sigma_u + 160}\right)}\ \text{mm}$$

where

k = 1,0 for shafts with integral coupling flanges complying with *Pt 11, Ch 2, 4.8 Couplings and transitions of diameters* or shrink fit couplings

= 1,10 for shafts with keyways, tapered or cylindrical connections, where the fillet radii in the transverse section of the bottom of the keyway are not less than 0,0125d

= 1,10 for shafts with transverse or radial holes (d_h) where the diameter of the hole does not exceed 0,3d

= 1,20 for shafts with longitudinal slots, *see Pt 11, Ch 2, 4.2 Intermediate shafts 4.2.7*

F = 95 for turbine installations, electric propulsion installations and diesel engine installations with slip type couplings

= 100 for other diesel engine installations

= *P* and *R* are as defined in *Pt 9 General Requirements for Machinery* (losses in gearboxes and bearings are to be disregarded)

σ_u = specified minimum tensile strength of the shaft material, in N/mm^2.

4.2.2 Beyond a length of 0,2d from the end of a keyway, transverse hole or radial hole and 0,3d from the end of a longitudinal slot, the diameter of the shaft may be gradually reduced to that determined with k = 1,0.

4.2.3 For shafts with design features other than stated as above, the value of k will be specially considered.

4.2.4 The Rule diameter of the intermediate shaft for diesel engines, turbines and electric propelling motors may be reduced by 3,5 per cent for craft classed G1 (Service Group 1), *see Pt 1, Ch 2, 3.5 Service area restriction notations*.

4.2.5 For shrink fit couplings, k refers to the plain shaft section only. Where shafts may experience vibratory stresses close to the permissible stresses for continuous operation, an increase in diameter to the shrink fit diameter is to be provided, e.g. a diameter increase of 1 to 2 per cent and a blending radius as described in *Pt 11, Ch 2, 4.8 Couplings and transitions of diameters*.

4.2.6 Keyways are in general not to be used in installations with a barred speed range.

4.2.7 The application of k = 1,20 is limited to shafts with longitudinal slots having a length of less than 0,8d_o and a width greater than 0,15d_o and a diameter of central hole d_i of less than 0,7d_o, *see Pt 11, Ch 2, 4.5 Hollow shafts*. The end rounding of the slot is not to be less than half the width. An edge rounding should preferably be avoided as this increases the stress concentration slightly. The values of C_K, *see Table 1.3.1 C_k factors* in *Pt 13, Ch 1 Torsional Vibration*, are valid for 1, 2 and 3 slots, i.e. with slots at 360, 180 and 120 degrees apart respectively.

4.2.8 Where the intermediate shaft is constructed of the same material as the screwshaft and of a material listed in *Table 2.4.1 `A' Value for use in unprotected screwshaft formula* , the diameter of the intermediate shaft is not required to be greater than that of the screwshaft.

4.3 Thrust shafts

4.3.1 The diameter at the collars of the thrust shaft transmitting torque or in way of the axial bearing where a roller bearing is used as a thrust bearing is to be not less than that required for the intermediate shaft in accordance with *Pt 11, Ch 2, 4.2 Intermediate shafts* with a k value of 1,10. Beyond a length equal to the thrust shaft diameter from the collars, the diameter may be tapered down to that required for the intermediate shaft with a k value of 1,0. For the purpose of the foregoing calculations, σ_u is to be taken as the minimum tensile strength of the thrust shaft material, in N/mm^2.

4.4 Screwshafts and tube shafts

4.4.1 Screwshafts and tube shafts, (i.e. the shaft which passes through the sterntube, but does not carry the propeller), made from carbon manganese steel are to be protected by a continuous bronze liner, where exposed to sea water. Alternatively, the liner

may be omitted provided the shaft is arranged to run in an oil lubricated bush with an approved oil sealing gland at the after end. Lengths of shafting between sterntubes and brackets, which are readily visible when the craft is slipped, may be protected by coatings of an approved type.

4.4.2 Means for the protection of screwshafts and tubeshafts are not required when the shafts are made of corrosion resistant material.

4.4.3 The diameter, d_p of the protected forged steel screwshaft immediately forward of the forward face of the propeller boss or, if applicable, the forward face of the screwshaft flange, is to be not less than:

$$d_{\text{p}} = 100k\sqrt[3]{\frac{P}{R}\left(\frac{560}{\sigma_{\text{u}} + 160}\right)} \text{ mm}$$

where

k = 1,22 for a shaft carrying a keyless propeller fitted on a taper, or where the propeller is attached to an integral flange, and where the shaft is fitted with a continuous liner, a coating of an approved type, or is oil lubricated and provided with an approved type of oil sealing gland

= 1,26 for a shaft carrying a keyed propeller and where the shaft is fitted with a continuous liner, a coating of an approved type, or is oil lubricated and provided with an approved type of oil sealing gland

P and *R* are as defined in *Pt 9 General Requirements for Machinery* (losses in gearboxes and bearings are to be disregarded)

σ_u = specified minimum tensile strength of the shaft material, in N/mm^2 but is not to be taken as greater than 600 N/mm^2 , *see Pt 11, Ch 2, 3.1 Materials for shafts 3.1.4*.

4.4.4 The diameter, d_p of the screwshaft determined in accordance with *Pt 11, Ch 2, 4.4 Screwshafts and tube shafts 4.4.3* is to extend over a length not less than that to the forward edge of the bearing immediately forward of the propeller or 2,5d_p whichever is the greater.

4.4.5 The diameter of the portion of the screwshaft and tube shaft forward of the length required by *Pt 11, Ch 2, 4.4 Screwshafts and tube shafts 4.4.4* to the forward end of the forward sterntube seal is to be determined in accordance with *Pt 11, Ch 2, 4.4 Screwshafts and tube shafts 4.4.3* with a *k* value of 1,15. The change of diameter from that determined with *k* = 1,22 or 1,26 to that determined with *k* = 1,15 should be gradual, *see Pt 11, Ch 2, 4.8 Couplings and transitions of diameters*

4.4.6 Screwshafts which run in sterntubes and tube shafts may have the diameter forward of the forward sterntube seal gradually reduced to the diameter of the intermediate shaft. Abrupt changes in shaft section at the screwshaft/tube shaft to intermediate shaft couplings are to be avoided, *see Pt 11, Ch 2, 4.8 Couplings and transitions of diameters*.

4.4.7 The diameter of unprotected screwshafts and tube shafts of materials as shown in *Table 2.4.1 `A' Value for use in unprotected screwshaft formula* is to be not less than:

$$d_{\text{up}} = 128A\sqrt[3]{\frac{P}{R}}$$

where `A' is taken from *Table 2.4.1 `A' Value for use in unprotected screwshaft formula* and *P* and *R* are as defined in *Pt 9 General Requirements for Machinery*.

Table 2.4.1 `*A*' Value for use in unprotected screwshaft formula

Material	'*A*' Value
Stainless steel type 316 (austenitic)	0,71
Stainless steel type 431 (martensitic)	0,69
Manganese bronze	0,8
Aluminium bronze	0,65
Nickel copper alloy - monel 400	0,65

Nickel copper alloy - monel K 500	0,55
Duplex steels	0,49

4.4.8 The diameter of unprotected screwshafts of materials as shown in *Table 2.4.1 `A' Value for use in unprotected screwshaft formula* forward of the forward sterntube seal is to be determined in accordance with *Pt 11, Ch 2, 4.4 Screwshafts and tube shafts 4.4.7* or *Pt 11, Ch 2, 4.4 Screwshafts and tube shafts 4.4.3*, whichever is less.

4.5 Hollow shafts

4.5.1 Where the thrust, intermediate, tube shafts and screwshafts have central holes having a diameter greater than 0,4 times the outside diameter, the equivalent diameter, d_e, of a solid shaft is not to be less than the Rule size, d, (of a solid shaft), where d_e is given by:

$$d_e = d_o \sqrt[3]{1 - \left(\frac{d_i}{d_o}\right)^4}$$

where

d_o = proposed outside diameter, in mm

d_i = diameter of central hole, in mm

4.5.2 Where the diameter of the central hole does not exceed 0,4 times the outside diameter, the diameter is to be calculated in accordance with the appropriate requirements for a solid shaft.

4.6 Cardan shafts

4.6.1 Cardan shafts, used in installations having more than one propulsion shaftline, are to be of an approved design, suitable for the designed operating conditions including short term high power operation. Consideration will be given to accepting the use of approved cardan shafts in single propulsion unit applications if a complete spare interchangeable end joint is provided on board.

4.6.2 Cardan shaft ends are to be contained within substantial tubular guards that also permit ready access for inspection and maintenance.

4.7 Coupling bolts

4.7.1 Close tolerance fitted bolts transmitting shear are to have a diameter, d_b, at the flange joining faces of the couplings not less than:

$$d_b = \sqrt{\frac{240}{nD}\frac{10^6}{\sigma_u}\frac{P}{R}} \text{ mm}$$

where

n = number of bolts in the coupling

D = pitch circle diameter of bolts, in mm

σ_u = specified minimum tensile strength of bolts, in N/mm^2

P and *R* are defined in *Pt 9 General Requirements for Machinery*.

4.7.2 At the joining faces of couplings, other than within the crankshaft and at the thrust shaft/crankshaft coupling, the Rule diameter of the coupling bolts may be reduced by 5,2 per cent for craft classed exclusively for smooth water service.

4.7.3 Where dowels or expansion bolts are fitted to transmit torque in shear they are to comply with the requirements of *Pt 11, Ch 2, 4.7 Coupling bolts 4.7.1* . The expansion bolts are to be installed, and the bolt holes in the flanges are to be correctly aligned in accordance with manufacturer's instructions.

4.7.4 The minimum diameter of tap bolts or of bolts in clearance holes at the joining faces of coupling flanges, pretensioned to 70 per cent of the bolt material yield strength value, is not to be less than:

$$d_R = 1,348\sqrt{\left(\frac{120\ 10^6\ FP(1+C)}{RD} + Q\right)\frac{1}{n\ \sigma_v}}$$

where d_R is taken as the lesser of:

(a) Mean of effective (pitch) and minor diameters of the threads.

(b) Bolt shank diameter away from threads. (Not for waisted bolts which will be specially considered.)

P and *R* are defined in *Pt 9 General Requirements for Machinery*.

F = 2,5 where the flange connection is not accessible from within the craft

= 2,0 where the flange connection is accessible from within the craft

C = ratio of vibratory/mean torque values at the rotational speed being considered

D = pitch circle diameter of bolt holes, in mm

Q = external load on bolt in N (+ve tensile load tending to separate flange, -ve)

n = number of tap or clearance bolts

σ_y = bolt material yield stress in N/mm^2.

4.7.5 Consideration will be given to those arrangements where the bolts are pretensioned to loads other than 70 per cent of the material yield strength.

4.7.6 Where clamp bolts are fitted they are to comply with the requirements of *Pt 11, Ch 2, 4.7 Coupling bolts 4.7.4* and are to be installed, and the bolt holes in the flanges correctly aligned, in accordance with manufacturer's instructions.

4.8 Couplings and transitions of diameters

4.8.1 The minimum thicknesses of the coupling flanges are to be equal to the diameters of the coupling bolts at the face of the couplings as required by *Pt 11, Ch 2, 4.7 Coupling bolts 4.7.1*, and for this purpose the minimum tensile strength of the bolts is to be taken as equivalent to that of the shafts. For intermediate, thrust shafts, and the inboard end of the screwshaft, the thickness of the coupling flange is in no case to be less than 0,20 of the diameter of the intermediate shaft as required by *Pt 11, Ch 2, 4.2 Intermediate shafts*.

4.8.2 The fillet radius at the base of the coupling flange, integral with the shaft, is to be not less than 0,08 of the diameter of the shaft at the coupling. The fillets are to have a smooth finish and are not to be recessed in way of nut and bolt heads.

4.8.3 Where the propeller is attached by means of a flange, the thickness of the flange is to be not less than 0,25 of the actual diameter of the adjacent part of the screwshaft. The fillet radius at the base of the coupling flange is to be not less than 0,125 of the diameter of the shaft at the coupling.

4.8.4 All couplings which transmit torque are to be of approved dimensions.

4.8.5 Where couplings are separate from the shafts, provision is to be made to resist the astern pull.

4.8.6 Where a coupling is shrunk on to the parallel portion of a shaft or is mounted on a slight taper, e.g. by means of the oil pressure injection method, the assembly is to meet the requirements of *Pt 11, Ch 2, 4.11 Interference fit assemblies*.

4.8.7 Transitions of diameters are to be designed with either a smooth taper or a blending radius. In general, a blending radius equal to the change in diameter is recommended.

4.9 Tooth couplings

4.9.1 The contact stress, S_c, at the flanks of mating teeth of a gear coupling is not to exceed that given in *Table 2.4.2 Allowable S_c values* , where

$$S_c = \frac{24, 10^6 P}{Rd_p\ bhz}\ \text{N/mm}^2$$

where

P and *R* are defined in *Pt 9 General Requirements for Machinery*.

d_p = pitch circle diameter of coupling teeth, in mm

b = tooth facewidth, in mm

h = tooth height, in mm

z = number of teeth (per coupling half)

Table 2.4.2 Allowable S_c values

Tooth material surface treatment	Allowable S_c Value N/mm^2
Surface hardened teeth	19
Through hardened teeth	11

4.9.2 Where experience has shown that under similar operating and alignment conditions, a higher tooth loading can be accommodated full details are to be submitted for consideration.

4.10 Flexible couplings

4.10.1 Details of flexible couplings are to be submitted together with the manufacturer's rating capacity, for the designed operating conditions including short term high power operation. Verification of coupling characteristics will be required.

4.10.2 In determining the allowable mean, maximum and vibratory torque ratings consideration of the mechanical properties of the selected elastic element type in compression, shear and fatigue loading together with heat absorption/generation is to be given.

4.10.3 In determining the allowable torque ratings of the steel spring couplings, consideration of the material mechanical properties to withstand fatigue loading and overheating is to be given.

4.11 Interference fit assemblies

4.11.1 The interference fit assembly is to have a capacity to transmit a torque of $S.T_{max}$ without slippage.

Note For guidance purposes only $T_{max} = T_{mean}$ (1+C)

Where C is to be taken from *Table 2.4.3 `C' values for guidance purposes*

S = 2,0 for assemblies accessible from within the vessel

= 2,5 for assemblies not accessible from within the vessel

4.11.2 The effect of any axial load acting on the assembly is to be considered.

Table 2.4.3 `*C*' values for guidance purposes

Coupling location	*C*
High Speed Shafting - I.C engine driven	0,3
High Speed Shafting - Electric Motor or Turbine driven	0,1
Low Speed Shafting - main or PTO stage gearing	0,1

4.11.3 The resulting equivalent von Mises stress in the assembly is not to be greater than the yield strength of the component material.

4.11.4 Reference marks are to be provided on the adjacent surfaces of parts secured by shrinkage alone.

4.12 Keys and keyways for propeller connections

4.12.1 Round ended or sled-runner ended keys are to be used, and the keyways in the propeller boss and cone of the screwshaft are to be provided with a smooth fillet at the bottom of the keyways. The radius of the fillet is to be at least 0,0125 of the diameter of the screwshaft at the top of the cone. The sharp edges at the top of the keyways are to be removed.

4.12.2 Two screwed pins are to be provided for securing the key in the keyway, and the forward pin is to be placed at least one-third of the length of the key from the end. The depth of the tapped holes for the screwed pins is not to exceed the pin diameter, and the edges of the holes are to be slightly bevelled. The omission of pins for keys for small diameter shafts will be specially considered.

4.12.3 The distance between the top of the cone and the forward end of the keyway is to be not less than 0,2 of the diameter of the screwshaft at the top of the cone.

4.12.4 The effective sectional area of the key in shear, is to be not less than:

$$\frac{155\,d^3}{\sigma_{\text{u}} d_1} \text{ mm}^2$$

where

d = diameter, in mm, required for the intermediate shaft determined in accordance with *Pt 11, Ch 2, 4.2 Intermediate shafts*, based on material having a specified minimum tensile strength of 400 N/mm^2 and k= 1

d_1 = diameter of shaft at mid-length of the key, in mm

σ_u = specified minimum tensile strength (UTS) of the key material, N/mm^2.

4.12.5 The effective area in crushing of key, shaft or boss is to be not less than:

$$\frac{24\,d^3}{\sigma_{\text{y}} d_1} \text{ mm}^2$$

where

σ = yield strength of key, shaft or boss material as appropriate, N/mm^2

4.13 Keys and keyways for inboard shaft connections

4.13.1 Round ended keys are to be used and the keyways are to be provided with a smooth fillet at the bottom of the keyways. The radius of the fillet is to be at least 0,0125 of the diameter of the shaft at the coupling. The sharp edges at the top of the keyways are to be removed.

4.13.2 The effective area of the key in shear, A, is to be not less than:

$$A = \frac{126\,d^3}{\sigma_{\text{u}}\, d_1} \text{ mm}^2$$

where

d = diameter, in mm, required for the intermediate shaft determined in accordance with *Pt 11, Ch 2, 4.2 Intermediate shafts*, based on material having a specified minimum tensile strength of 400 N/mm^2 and k = 1

d_1 = diameter of shaft at mid-length of the key, in mm

σ_u = specified minimum tensile strength (UTS) of the key material, N/mm^2

Alternatively, consideration will be given to keys conforming to the design requirements of a recognised National Standard.

4.14 Corrosion resistant liners on shafts

4.14.1 Liners may be bronze, gunmetal, stainless steel or other approved alloy.

4.14.2 The thickness, t, of liners fitted on screwshafts or on tube shafts, in way of the bushes, is to be not less, when new, than given by the following formula:

$$t = \frac{D + 230}{32} \text{ mm}$$

where

t = thickness of the liner, in mm

D = diameter of the screwshaft or tube shaft under the liner, in mm

4.14.3 The thickness of a continuous liner between the bushes is to be not less than 0,75t.

4.14.4 Continuous liners are to be fabricated or cast in one piece.

4.14.5 Where liners consist of two or more lengths, these are to be butt welded together. In general, the lead content of the gunmetal of each length forming a butt welded liner is not to exceed 0,5 per cent. The composition of the electrodes or filler rods is to be substantially lead-free.

4.14.6 The circumferential butt welds are to be of multi-run, full penetration type. Provision is to be made for contraction of the weld by arranging for a suitable length of the liner containing the weld, if possible about three times the shaft diameter, to be free of the shaft. To prevent damage to the surface of the shaft during welding, a strip of heat resisting material covered by a copper strip should be inserted between the shaft and the liner in way of the joint. Other methods for welding this joint may be accepted if approved. The welding is to be carried out by an approved method and to the Surveyor's satisfaction.

4.14.7 Each continuous liner or length of liner is to be tested by hydraulic pressure to 2,0 bar after rough machining.

4.14.8 Liners are to be carefully shrunk onto the shafts by hydraulic pressure. Pins are not to be used to secure the liners.

4.14.9 Effective means are to be provided for preventing water from reaching the shaft at the part between the after end of the liner and the propeller boss.

4.15 Intermediate bearings

4.15.1 Long unsupported lengths of shafting are to be avoided by the fitting of steady bearings at suitable positions, *see Pt 13 Shaft Vibration and Alignment*.

4.16 Sternbushes and sterntube arrangements

4.16.1 Where the sterntube or sternbushes are to be installed using a resin, of an approved type, the following requirements are to be met:

(a) Pouring and venting holes are to be provided at opposite ends with the vent hole at the highest point.
(b) The minimum radial gap occupied by the resin is to be not less than 6 mm at any one point with a nominal resin thickness of 12 mm.
(c) In the case of oil lubricated sterntube bearings, the arrangement of the oil grooves is to be such as to promote a positive circulation of oil in the bearing.
(d) Provision is to be made for the remote measurement of the temperature at the aft end of the aft bearing, with indication and alarms at the control stations.

4.16.2 The length of the bearing in the sternbush next to and supporting the propeller is to be as follows:

(a) For water lubricated bearings which are lined with lignum vitae, rubber composition or staves of synthetic material, the length is to be not less than 4,0 times the rule diameter of the shaft in way of the bearing.
(b) For water lubricated bearings lined with two or more circumferentially spaced sectors, of synthetic material, without axial grooves in the lower half, the length of the bearing is to be such that the nominal bearing pressure will not exceed 0,55 MPa. The length of the bearing is to be not less than 2,0 times the rule diameter of the shaft in way of the bearing.
(c) For oil lubricated bearings of synthetic material, the length of the bearing is, in general, to be not less than 2,0 times the rule diameter of the shaft in way of the bearing. The nominal bearing pressure is not to exceed the maximum for which the synthetic material has been approved.
(d) For bearings which are white-metal lined, oil lubricated and provided with an approved type of oil sealing gland, the length of the bearing is to be approximately 2,0 times the rule diameter of the shaft in way of the bearing and is to be such that the nominal bearing pressure will not exceed 0,8 MPa. The length of the bearing is to be not less than 1,5 times its diameter.

(e) For bearings of cast iron and bronze which are oil lubricated and fitted with an approved oil sealing gland, the length of the bearing is, in general, to be not less than 4,0 times the rule diameter of the shaft in way of the bearing.

(f) For bearings which are grease lubricated, the length of the bearing is to be not less than 4,0 times the rule diameter of the shaft in way of the bearing. Other lengths may be considered upon application, subject to the provision of suitable supporting in-service or testing evidence at relevant shaft pressures and velocities.

4.16.3 Synthetic materials for application as stern tube bearings are to be approved in accordance with *Rules for the Manufacture, Testing and Certification of Materials, July 2021*, *Ch 14, 2.13 Sterntube bearings*.

4.16.4 Sternbushes are to be adequately secured in housings.

4.16.5 Forced water lubrication is to be provided for all bearings lined with rubber or synthetic material. The supply of water may come from a circulating pump or other pressure source. Flow indicators are to be provided for the water service to the bearings. The water grooves in the bearings are to be of ample section and of a shape which will be little affected by weardown, particularly for bearings of the synthetic material.

4.16.6 The shut-off valve or cock controlling the supply of water is to be fitted directly to the after peak bulkhead, or to the sterntube where the water supply enters the sterntube forward of the bulkhead.

4.16.7 Oil sealing glands must be capable of accommodating the effects of differential expansion between hull and line of shafting for all sea temperatures in the proposed area of operation. This requirement applies particularly to those glands which span the gap and maintain oiltightness between the sterntube and the propeller boss.

4.16.8 Where a tank supplying lubricating oil to the sternbush is fitted, it is to be located above the load waterline and is to be provided with a low level alarm device in the machinery space, *see also Pt 11, Ch 2, 5.1 Unattended machinery 5.1.1*.

4.16.9 For oil lubricated bearings of synthetic material, the flow of lubricant is to be such that overheating, under normal operating conditions, cannot occur.

4.16.10 Where sternbush bearings are oil lubricated, provision is to be made for cooling the oil by maintaining water in the after peak tank above the level of the sterntube or by other approved means.

4.16.11 Means for ascertaining the temperature of the sternbush bearings are to be provided, e.g. monitoring of the temperature of the oil in the sterntube.

4.16.12 Where an ***IWS** (In-Water Survey) notation is to be assigned, for water lubricated bearings, means are to be provided for ascertaining the clearance in the sternbush with the craft afloat.

4.17 Vibration and alignment

4.17.1 For the requirements for torsional, axial and lateral vibration, and for alignment of the shafting, *see Pt 13 Shaft Vibration and Alignment*.

■ *Section 5*
Control and monitoring

5.1 Unattended machinery

5.1.1 Where sterntube lubrication oil systems are fitted with automatic or remote controls so that under normal operating conditions they do not require any manual intervention by the operators, they are to be provided with the alarms indicated in *Table 2.5.1 Alarms*.

Table 2.5.1 Alarms

Item	Alarm
Sterntube lubricating oil tank level	Low
Sterntube bearing temperature (oil lubricated)	High

5.2 Screwshaft Condition Monitoring (SCM)

5.2.1 For vessels where the ShipRight descriptive note SCM (Screwshaft Condition Monitoring) is requested, the requirements in either *Pt 11, Ch 2, 5.2 Screwshaft Condition Monitoring (SCM) 5.2.2* or *Pt 11, Ch 2, 5.2 Screwshaft Condition Monitoring (SCM) 5.2.3* are to be satisfied.

5.2.2 Oil lubricated bearings:

(a) Arrangements are to be provided to allow analysis of the lubricating oil. Oil samples are to be taken under service conditions and are to be representative of the oil within the sterntube, sampling arrangements are to meet the requirements of *Pt 15, Ch 3, 6.4 Lubricating oil contamination 6.4.5*.

(b) Bearing temperature sensor arrangement is to be designed with either:

  (i) sufficient redundancy in the event of failure of one sensing element and/or its associated cabling; or

  (ii) means to allow replacement of a damaged sensor without requiring dry-docking or divers.

(c) Facilities are to be provided for measurement of bearing weardown.

(d) Approved oil glands that are capable of being replaced without removal of the propeller or withdrawal of the screwshaft are to be fitted.

5.2.3 Water lubricated bearings:

(a) An approved means of monitoring and recording variations in the flow rate of lubricating water using two independent sensors is to be provided.

(b) An approved means of monitoring and recording variations in the shaft power transmission is to be provided.

(c) The maximum permitted weardown of the sternbush is to be indicated by the manufacturer. The maximum weardown is to include both the absolute maximum permitted weardown and the weardown at which it is recommended to carry out an inspection and maintenance. An approved means of monitoring bearing wear is to be provided. An alignment analysis considering both the newly installed clearance and the proposed absolute maximum allowable weardown, demonstrating that the system will operate satisfactorily within these two limits, is to be submitted and approved.

(d) For open loop systems the manufacturer is to submit information regarding the required standard of lubricating water filtration and lubricating water filters or separators are to be fitted which are able to achieve this requirement. The lubricating water supply is to be fitted with either continuous water sediment measuring equipment, turbidity monitoring equipment or an LR approved extractive sampling and testing procedure.

(e) Where a closed cycle water system is used, arrangements are to allow analysis of the water for at least the following parameters:

  (i) Chloride content.

  (ii) Bearing material and metal particles content.

  Water samples are to be representative of the water circulating within the sterntube.

(f) The shaft is to either be constructed of corrosion resistant material or protected with a corrosion resistant protective liner or coating approved by LR. Where a protective liner or coating is used, this is to meet the requirements of *Pt 11, Ch 2, 4.14 Corrosion resistant liners on shafts*, and a means of assessing the condition of this liner is to be submitted and approved.

(g) Glands are to be capable of being replaced without withdrawal of the screwshaft.

(h) There is to be a shaft starting/clutch engagement block to inhibit starting the shaft until lubricating water flow has been established. This is to only act as a starting block; for lubricating water flow alarm *see Table 2.5.2 Alarm and safeguard for water lubricated bearings*.

(i) Alternative arrangements are subject to special consideration.

Table 2.5.2 Alarm and safeguard for water lubricated bearings

Item	Alarm	Note
Lubricating water flow	Low	*See Pt 11, Ch 2, 5.2 Screwshaft Condition Monitoring (SCM) 5.2.3.(h)*

■ Section 6
Requirements for craft which are not required to comply with the HSC Code

6.1 General

6.1.1 Service craft of less than 24 m do not have to comply with *Pt 11, Ch 2, 1.3 Clutches 1.3.1* in respect of emergency operation of clutches on single screw installations.

6.2 Details to be submitted

6.2.1 The corrosion fatigue strength of corrosion resistant shaft material need not be submitted if the material is as shown in *Table 2.4.1 `A' Value for use in unprotected screwshaft formula* , *see also Pt 11, Ch 2, 2.2 Calculations and specifications*.

6.3 Materials

6.3.1 The proposals to use extruded non-ferrous or composite materials will receive special consideration.

6.3.2 For the survey and testing of shaft material, *see* the*Rules for the Manufacture, Testing and Certification of Materials, July 2021*.

6.4 Sternbushes and sterntube arrangement

6.4.1 For service craft less than 24 m, the requirements of *Pt 11, Ch 2, 4.16 Sternbushes and sterntube arrangements 4.16.1* do not apply. Sterntube bearings of approved plastics materials are to be installed so as to ensure a supply of water for lubrication in accordance with the bearing manufacturer's recommendations.

6.4.2 The aftermost propeller shaft bearing in the sterntube is to be secured to prevent rotational and axial movement.

6.4.3 For service craft less than 24 m, the requirements of *Pt 11, Ch 2, 4.16 Sternbushes and sterntube arrangements 4.16.10* do not apply.

6.4.4 The lubrication of propulsion shafting bearings on SES craft less than 24 m will be considered.

6.5 Alarms

6.5.1 The requirements of *Pt 11, Ch 2, 5.1 Unattended machinery 5.1.1* do not apply to service craft less than 24 m.

■ Section 7
Approval of alloy steel used for intermediate shaft material

7.1 Application

7.1.1 The requirements of *Pt 11, Ch 2, 7 Approval of alloy steel used for intermediate shaft material* are, in addition to the requirements of the *Rules for the Manufacture, Testing and Certification of Materials, July 2021*, *Ch 5, 3 Forgings for shafting and machinery*, to be applied to the approval of alloy steel which has a minimum specified tensile strength greater than 800 N/mm^2, but, not exceeding 950 N/mm^2 intended for use as intermediate shaft material.

7.2 Torsional fatigue test

7.2.1 A torsional fatigue test is to be performed to verify that the material exhibits a similar fatigue life to conventional steels. The torsional fatigue strength of the material is to be equal to or greater than the permissible torsional vibration stress τ_C given by the formulae in *Pt 13, Ch 1, 3.2 Limiting stress in propulsion shafting*.

7.2.2 The test is to be carried out with notched and unnotched specimens respectively. For calculation of the stress concentration factor of the notched specimen, fatigue strength reduction factor β should be evaluated in consideration of the severest torsional stress concentration factor in the design criteria.

7.2.3 Test procedures are to be in accordance with Section 10 of ISO 1352 and the test conditions applied are to be in accordance with *Table 2.7.1 Test Condition*. Mean surface roughness is to be less than 0,2μm Ra with the absence of localised machining marks verified by visual examination at low magnification (x20) as required by Section 8.4 of ISO 1352.

Table 2.7.1 Test Condition

Loading type	Torsion
Stress ratio	R = -1
Load waveform	Constant amplitude sinusoidal
Evaluation	S-N curve
Number of cycles for test termination	1x 10^7

7.2.4 The measured torsional fatigue strength for continuous operation, τ_c, and torsional fatigue strength for transient operation, τ_t, are to be equal to or greater than the values given by the following formulae:

$$\tau_c \geq \frac{\sigma_u + 160}{6} \cdot C_{k.} C_d \quad \text{for} \quad r = 0$$

$$\tau_t \geq 1,7 \cdot \tau_c \cdot \frac{1}{\sqrt{C_k}}$$

where

C_k = a factor for different shaft design features, *see Table 1.3.1 C k factors , Pt 13, Ch 1, 3.1 Symbols and definitions 3.1.4*

C_d = size factor, *see Pt 13, Ch 1, 3.1 Symbols and definitions 3.1.1*

σ_u = specified minimum tensile strength of the shaft material, in N/mm^2

r = speed ratio, N/N$_s$, *see Pt 13, Ch 1, 3.1 Symbols and definitions 3.1.1*

7.3 Material requirements

7.3.1 The steels are to have a degree of cleanliness as shown in *Table 2.7.2 Cleanliness requirements* requirements when tested according to ISO 4967 method A. Representative samples are to be obtained from each heat of forged or rolled products.

Table 2.7.2 Cleanliness requirements

Inclusion group	Series	Limiting chart diagram index I
Type A	Fine	1
	Thick	1
Type B	Fine	1,5
	Thick	1
Type C	Fine	1
	Thick	1
Type D	Fine	1
	Thick	1
Type DS	-	1

Contents

Section 1
General requirements

1.1 Application

1.1.1 This Chapter is to be read in conjunction with the General Requirements for Machinery in *Pt 9 General Requirements for Machinery*.

1.2 Power ratings

1.2.1 In this Chapter where the dimensions of main propulsion components are determined from shaft power, *P*, in kW, and revolutions per minute, *R*, the values to be used are those defined in *Pt 9 General Requirements for Machinery*.

1.3 Highly skewed propellers

1.3.1 The maximum skew angle of a propeller blade is defined as the angle, in projected view of the blade, between a line drawn through the blade tip and the shaft centreline and a second line through the shaft centreline which acts as a tangent to the locus of the mid-points of the helical blade sections, *see Figure 1.1.1 Definition of skew angle*.

1.4 Supercavitating propellers

1.4.1 A supercavitating propeller is defined as one in which the sheet cavity is designed to cover the entire blade width over at least the outer 50 per cent of the blade span.

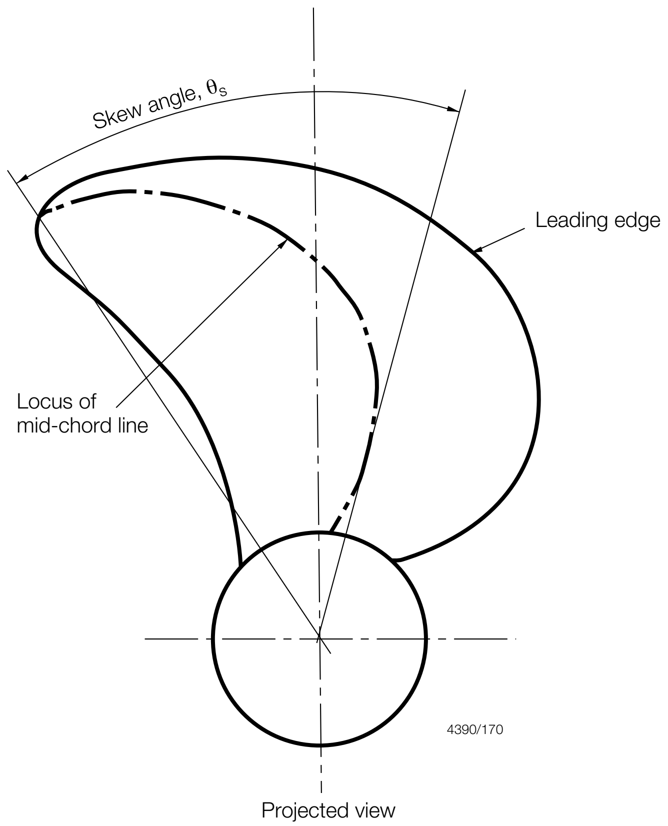


Figure 1.1.1 Definition of skew angle

■ Section 2
Plans and particulars

2.1 Particulars to be submitted

2.1.1 At least three copies of the following plans and information are to be submitted:

2.2 Plans

2.2.1 A plan of the propeller, together with the following particulars is to be submitted:

(a) Maximum blade thickness of the expanded cylindrical section considered, in mm, excluding any allowance for fillet, T, in mm.
(b) Maximum shaft power, P, in kW, *see Pt 9 General Requirements for Machinery*.
(c) Estimated craft speed at design loaded draught in the free running condition at maximum shaft power and corresponding revolutions per minute (*see Pt 12, Ch 1, 2.2 Plans 2.2.1.(b)* and *Pt 12, Ch 1, 2.2 Plans 2.2.1.(d)*.
(d) Revolutions per minute of the propeller at maximum power, R.
(e) Propeller diameter, D, in metres.
(f) Pitch at 25 per cent radius (for solid propellers only), $P_{0,25}$, in metres.
(g) Pitch at 35 per cent radius (for controllable pitch propellers only), $P_{0,35}$, in metres.
(h) Pitch at 60 per cent radius, $P_{0,6}$, in metres.
(i) Pitch at 70 per cent radius, $P_{0,7}$, in metres.
(j) Length of blade section of the expanded cylindrical section at 25 per cent radius (for solid propellers only), $L_{0,25}$, in mm.

(k) Length of blade section of the expanded cylindrical section at 35 per cent radius (for controllable pitch propellers only), $L_{0,35}$, in mm.
(l) Length of blade section of the expanding cylindrical section at 60 per cent radius, $L_{0,6}$, in mm.
(m) Rake at blade tip measured at shaft axis (backward rake positive, forward rake negative), *A*, in mm.
(n) Number of blades, *N*.
(o) Developed area ratio, *B*.
(p) Material: type and specified minimum tensile strength.
(q) Skew angle, θ_s, in degrees, *see Figure 1.1.1 Definition of skew angle*.
(r) Connection of propeller to shaft- details of fit, push up and securing.
(s) Keyed connection details.
(t) Details of control/hydraulic system and pressures for CP Propellers actuating mechanisms.
(u) Inertia of propeller assembly, kgm^2.
(v) Total mass of propeller assembly, kg.

2.2.2 For propellers having a skew angle equal or greater than 50° in addition to the particulars detailed in *Pt 12, Ch 1, 2.2 Plans 2.2.1* details are to be submitted of:

(a) Full blade section details at each radial station defined for manufacture.
(b) A detailed blade stress computation supported by the following hydrodynamic data for the ahead mean wake condition and when absorbing full power:
    (i) Radial distribution of lift and drag coefficients, section inflow velocities and hydrodynamic pitch angles.
    (ii) Section pressure distributions calculated by either an advised viscid or viscous procedure.

2.3 Calculations and information

2.3.1 In cases where the craft has been the subject of model wake field tests a copy of the results is to be submitted.

2.3.2 The following information is to be submitted as applicable:

- For controllable pitch propellers plans (in diagrammatic form) of the hydraulic systems together with pipe material and working pressures.
- Details of control engineering aspects in accordance with *Pt 16 Control and Electrical Engineering*.
- Calculations, or relevant documentation indicating the suitability of all components for short term high power operation.
- Where undertaken, fatigue strength analysis of components indicating a factor of safety of 1,5 at the design loads.
- For cases where the propeller material is not specified in *Table 1.3.1 Materials for propellers*, details of the chemical composition, mechanical properties and density are to be provided, together with results of fatigue tests in sea water in order to assign a value for *U*.

■ *Section 3* **Materials**

3.1 Castings for propellers

3.1.1 Castings for propellers and propeller blades are to comply with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials, July 2021* (hereinafter referred to as the Rules for Materials). The chemical composition and mechanical properties of steel castings are given in *Ch 4, 5 Castings for propellers* of the Rules for Materials and those of the copper alloys are given in *Ch 9, 1 Castings for propellers*of the Rules for Materials.

3.1.2 The specified minimum tensile strength of the castings is to be not less than stated in *Table 1.3.1 Materials for propellers*.

Table 1.3.1 Materials for propellers

Material	Specified minimum tensile strength N/mm^2	G Density g/cm^3	U Allowable stress N/mm^2
Carbon steels	400	7,9	20,6
Low alloy steels	440	7,9	20,6
13% chromium stainless steels	540	7,7	41
Chromium - nickel austenitic stainless steel	450	7,9	41
Duplex stainless steels	590	7,8	41
Grade Cu 1 Manganese bronze (high tensile brass)	440	8,3	39
Grade Cu 2 Ni-Manganese bronze (high tensile brass)	440	8,3	39
Grade Cu 3 Ni-Aluminium bronze	590	7,6	56
Grade Cu 4 Mn-Aluminium bronze	630	7,5	46

3.1.3 Where propellers of carbon and low alloy steels shown in *Table 1.3.1 Materials for propellers* are provided with an approved method of cathodic protection, special consideration will be given to the value of *U*.

■ *Section 4* Propeller design

4.1 Minimum blade thickness

4.1.1 For propellers having a skew angle of less than 25° as defined in *Pt 12, Ch 1, 1.3 Highly skewed propellers 1.3.1*, the minimum blade thickness, *T*, of the propeller blades at 25 per cent radius for solid propellers, 35 per cent radius for controllable pitch propellers, neglecting any increase due to fillets, and at 60 per cent radius, is to be not less than:

$$T = \frac{KCA}{EFULN} + 100\sqrt{\frac{3150MP}{EFRULN}} \text{ mm}$$

where

L = $L_{0,25}$, $L_{0,35}$, or $L_{0,6}$, as appropriate

K = $\dfrac{GBD^3R^2}{675}$

G = density, in g/cm^3, *see Table 1.3.1 Materials for propellers*.

U = allowable stress, in N/mm^2 *see Pt 12, Ch 1, 4.1 Minimum blade thickness 4.1.2*, *Pt 12, Ch 1, 4.1 Minimum blade thickness 4.1.3*, *Pt 12, Ch 1, 4.1 Minimum blade thickness 4.1.4* and *Table 1.3.1 Materials for propellers*.

where

$E = \dfrac{actual\ face\ modulus}{0,09T^2L}$

For aerofoil sections with and without trailing edge washback, E may be taken as 1,0 and 1,25 respectively.

For solid propellers at 25 per cent radius

C = 1,0

$F = \dfrac{P_{0,25}}{D} + 0,8$

$M = 1,0 + \dfrac{3,75D}{P_{0,7}} + 2,8\dfrac{P_{0,25}}{D}$

For controllable pitch propellers at 35 per cent radius

C = 1,4

$F = \dfrac{P_{0,35}}{D} + 1,6$

$M = 1,35 + \dfrac{5D}{P_{0,7}} + 2,6\dfrac{P_{0,35}}{D}$

For all propellers at 60 per cent radius

C = 1,6

$F = \dfrac{P_{0,6}}{D} + 4,5$

$M = 1,35 + \dfrac{5D}{P_{0,7}} + 1,35\dfrac{P_{0,6}}{D}$

4.1.2 The fillet radius between the root of a blade and the boss of a propeller is to be not less than the Rule thickness of the blade or equivalent at this location. Composite radiused fillets or elliptical fillets which provide a greater effective radius to the blade are acceptable and are to be preferred. Where fillet radii of the required size cannot be provided, the value of U is to be multiplied by

$$\left(\frac{r}{T}\right)^{0.2}$$

where

r = proposed fillet radius at the root, in mm

T = Rule thickness of the blade at the root, in mm

Where a propeller has bolted-on blades, consideration is also to be given to the distribution of stress in the palms of the blades. In particular, the fillets of recessed bolt holes and the lands between bolt holes are not to induce stresses which exceed those permitted at the outer end of the fillet radius between the blade and the palm. Counterbored bolt holes in blade flanges are to be provided with adequate fillet radii at the bottom of the counter bore.

4.1.3 The value U may be increased by 10 per cent for twin screw and outboard propellers of triple screw craft.

4.1.4 For propellers having skew angles of 25° or greater, but less than 50°, the mid chord thickness, $T_{\text{sk}0,6}$, at the 60 per cent radius is to be not less than:

$$T_{\text{sk}0,6} = 0,54\ T_{0,6}\sqrt{(1 + 0,1\ \theta_s)}\ \text{mm}$$

The mid chord thickness, $T_{\text{sk root}}$, at 25 or 35 per cent radius, neglecting any increase due to fillets, is to be not less than:

$$T_{\text{sk root}} = 0,75\, T_{\text{root}} \sqrt[4]{(1 + 0,1\theta_s)}\ \text{mm}$$

where

θ_S = proposed skew angle as defined in *Pt 12, Ch 1, 1.3 Highly skewed propellers 1.3.1*

$T_{0,6}$ = thickness at 60 per cent radius, calculated by *Pt 12, Ch 1, 4.1 Minimum blade thickness 4.1.1*

$T_{\text{sk root}}$ = thickness at 25 per cent radius or 35 per cent radius, calculated by *Pt 12, Ch 1, 4.1 Minimum blade thickness 4.1.1*

The thickness at the remaining radii are to be joined by a fair curve and the sections are to be of suitable aerofoil section.

4.1.5 Results of detailed calculations where carried out, are to be submitted.

4.1.6 Where the design of a propeller has been based on analysis of reliable wake survey data in conjunction with a detailed fatigue analysis and is deemed to permit scantlings less than required by *Pt 12, Ch 1, 4.1 Minimum blade thickness*, a detailed stress analysis for the blades is to be submitted for consideration.

4.2 Interference fit of keyless propellers

4.2.1 The symbols used in *Pt 12, Ch 1, 4.2 Interference fit of keyless propellers 4.2.2* are defined as follows:

d_1 = diameter of the screwshaft cone at the mid-length of the boss or sleeve, in mm

d_3 = outside diameter of the boss at its mid-length, in mm

d_i = bore diameter of screwshaft, in mm

$k_3 = \dfrac{d_3}{d_1}$

$l = \dfrac{d_i}{d_1}$

$$p_1 = \frac{2M}{A_1 \theta_1 V_1}\left(-1 + \sqrt{1 + V_1\left(\frac{F^2{}_1}{M^2} + 1\right)}\right)$$

A_1 = contact area fitting at screwshaft, in mm^2

$$B_3 = \frac{1}{E_3}\left(\frac{k_3^2 + 1}{k_3^2 - 1} + v_3\right) + \frac{1}{E_1}\left(\frac{1 + l^2}{1 - l^2} - v_1\right)$$

C = 0 for turbine installations or electric propulsion

= $\dfrac{\textit{vibratory torque at the service speed}}{\textit{mean torque at the service speed}}$ for oil engine installations

E_1 = modulus of elasticity of screwshaft material, in N/mm^2

E_3 = modulus of elasticity of propeller material, in N/mm^2

$F_1 = \dfrac{2000Q}{d_1}(1 + C)$

M = propeller thrust, in N

Q = mean torque corresponding to P and R as defined in *Pt 9 General Requirements for Machinery*, in Nm

T_1 = temperature at time of fitting propeller on shaft, in °C

V_1 = $0,51\left(\frac{\mu_1}{\theta_1}\right)^2 - 1$

α_1 = coefficient of linear expansion of screwshaft material, in mm/mm/°C

α_3 = coefficient of linear expansion of propeller material, in mm/mm/°C

θ_1 = taper of the screwshaft cone, but is not to exceed $\frac{1}{15}$ on the diameter, i.e. $\theta_1 \leq \frac{1}{15}$

μ_1 = coefficient of friction for fitting of boss assembly on shaft

= 0,13 for oil injection method of fitting

ν_1 = Poisson's ratio for screwshaft material

ν_3 = Poisson's ratio for propeller material

4.2.2 Where it is proposed to fit a keyless propeller by the oil shrink method, the pull-up, δ on the screwshaft is to be not less than:

$$\delta = \frac{d_1}{\theta_1}\left(p_1 B_3 + \left(\alpha_3 - \alpha_1\right)\left(35 - T_1\right)\right) \text{ mm}$$

The yield stress or 0,2 per cent proof stress, σ_0, of the propeller material is to be not less than:

$$\sigma_0 = \frac{1,4}{B_3}\left(\frac{\theta_1 \delta_p}{d_1} + T_1\left(\alpha_3 - \alpha_1\right)\right)\frac{\sqrt{3k_3^4 + 1}}{k_3^2 - 1} \text{ N/mm}^2$$

where

δ_p = proposed pull-up at the fitting temperature. The start point load, *W*, to determine the actual pull-up is to be not less than:

= $W = A_1\left(0,002 + \frac{\theta_1}{20}\right)\left(p_1 + \frac{18}{B_3}\left(\alpha_3 - \alpha_1\right)\right)$N.

4.3 Keyed propellers pushed up by an hydraulic nut

4.3.1 Calculations are to be undertaken to show that the proof stress of the boss material is not exceeded in way of the keyway root fillet radius. In order to reduce the likelihood of frettage a grip stress of not less than 20 N/mm^2 between boss and shaft is to be achieved.

4.4 Propeller boss

4.4.1 The forward edge of the bore of the propeller boss is to be rounded to a 6 mm radius. In the case of keyed propellers, the length of the forward fitting surface is to be about one diameter.

4.4.2 Drilling holes through propeller bosses is to be avoided, except where it is essential to the design.

4.5 Fixed and steering nozzles

4.5.1 The requirements for scantlings for fixed and steering nozzles are given in *Pt 3, Ch 3, 4 Fixed and steering nozzles, bow and stern thrust units*.

Section 5
Piping systems

5.1 General

5.1.1 The piping system for a controllable pitch propeller is to comply with the general design requirements given in *Pt 15 Piping Systems and Pressure Plant*.

5.1.2 The specific requirements for lubricating hydraulic oil systems and standby arrangements are given in *Pt 15 Piping Systems and Pressure Plant*.

5.1.3 The hydraulic power operating systems are to be provided with arrangements to maintain the cleanliness of the hydraulic fluid, taking into consideration the type and design of the hydraulic system.

Section 6
Control and monitoring

6.1 General

6.1.1 Control and monitoring is to comply with the requirements of *Pt 16, Ch 1 Control Engineering Systems*.

6.2 Automatic and remote controls

6.2.1 Where controllable pitch propellers are fitted with automatic or remote controls so that under normal operating conditions they do not require any manual intervention by the operators, they are to be provided with the alarms and safety arrangements required by *Pt 12, Ch 1, 6.2 Automatic and remote controls 6.2.2*, *Pt 12, Ch 1, 6.2 Automatic and remote controls 6.2.3* and *Table 1.6.1 Alarms*.

6.2.2 For controllable pitch propellers for main propulsion, a standby or alternative power source of actuating medium for controlling the pitch of the propeller blades is to be provided. Automatic start of the standby pump supplying hydraulic power for pitch control is to be provided.

Table 1.6.1 Alarms

Item	Alarm	Note
Hydraulic system pressure	Low	-
Hydraulic oil supply tank level	Low	-
Hydraulic oil temperature	High	Where an oil cooler is fitted
Power supply to the control system between the remote control station and hydraulic actuator	Failure	Failure of any power supply to a control system is to operate an audible and visual alarm
Propulsion motor	Overload	*SeePart 16*

6.2.3 For controllable pitch propellers, a shaft speed indicator and a pitch indicator which shows the degree of pitch as a measure of the propeller blade or actuator movement are to be provided at each station from which it is possible to control shaft speed or propeller pitch.

Section 7
Requirements for craft which are not required to comply with the HSC Code

7.1 Propellers not exceeding one metre in diameter

7.1.1 The materials and the scantlings need not comply with *Pt 12, Ch 1, 1 General requirements* to *Pt 12, Ch 1, 3 Materials* inclusive or *Pt 12, Ch 1, 4.1 Minimum blade thickness* inclusive.

7.1.2 Propellers for service craft less than 24 m and main engine power output not exceeding 500kW are to be manufactured from materials in accordance with the *Rules for the Manufacture, Testing and Certification of Materials, July 2021* at a works recognised for the quality of its casting and machining, and be free from defects.

7.1.3 Certificates of construction are not required.

7.1.4 Specific requirements for the piping systems are given in *Pt 15 Piping Systems and Pressure Plant*.

7.1.5 The alarm and monitoring arrangements, and for controllable pitch propellers, the safety arrangements and standby power sources, will be specially considered, *see also Pt 16 Control and Electrical Engineering*.

7.2 Alternative materials and design

7.2.1 Propellers made from materials not listed in the *Rules for the Manufacture, Testing and Certification of Materials, July 2021* or of unusual form or design will be specially considered.

■ *Section 1* Scope

1.1 General

1.1.1 For the purposes of these Rules, a water jet propulsion unit is described as a machine which takes in water, by means of a suitable inlet and conduit, and accelerates the mass of water using an impeller and nozzle to form a jet propulsion system. The water jet system comprises the unit and its associated actuation and control devices. The detail of the prime mover is excluded but not its effect on the water jet system.

1.1.2 This Chapter defines the requirements for the design and service life of marine water jet propulsion systems and is to be read in conjunction with the General Requirements for the Design and Construction of Machinery in *Pt 12, Ch 1 Propellers*.

1.1.3 The requirements for a fixed or steerable water jet propulsion system rated at 500 kW and above, which is integral with the ship's hull structure and forms a means of main propulsion, are detailed in this Chapter. This includes support arrangements, controls and the systems necessary to maintain operation and functionality of the water jet unit.

1.1.4 These requirements relate to water jets driven by axial or mixed flow pumps. Where units driven by radial flow pumps or inducers are proposed, details are to be submitted for consideration.

■ *Section 2* General requirements

2.1 Water jet arrangement

2.1.1 In general, for a ship to be assigned an unrestricted service notation, a minimum of two water jet systems is to be provided where these form the sole means of propulsion. For ships where a single water jet system is the sole means of propulsion, a detailed engineering and safety justification is to be evaluated by LR, *see Pt 12, Ch 2, 2.3 Calculations and information 2.3.22*. This evaluation process will include a risk analysis, using a recognised technique to verify that sufficient levels of redundancy and monitoring are incorporated in the water jet unit's essential support systems and operating equipment.

2.1.2 Water jet propulsion units are to be capable of continuous operation between their maximum and minimum output power rating at specified operating conditions, *see Pt 12, Ch 1, 3 Materials* and within the operational service profiles defined by *Pt 12, Ch 2, 2.3 Calculations and information 2.3.11* and *Pt 12, Ch 2, 2.3 Calculations and information 2.3.12*.

2.1.3 It is the Shipbuilder's responsibility to ensure that all of the installed equipment is suitable for operation in the location and under the environmental conditions defined in *Pt 12, Ch 1 Propellers*. Where anticipated environmental conditions are outside these limits or where additional conditions are to be considered, such as vibration and impulsive accelerations, requirements and details of compliance are to be submitted to LR.

2.2 Plans to be submitted

2.2.1 Plans, in triplicate, and information as detailed below and in *Pt 12, Ch 2, 2.3 Calculations and information* and *Pt 12, Ch 2, 2.4 Failure Mode and Effects Analysis (FMEA)* are to be submitted for consideration.

2.2.2 General arrangement plans showing details of the following:

(a) Shafting assembly indicating bearing positions.
(b) Steering assembly.
(c) Reversing assembly.
(d) Shaft sealing arrangement assembly.
(e) Longitudinal section of the complete water jet unit.

2.2.3 Detailed and dimensioned plans indicating scantlings, materials of construction and, where applicable, surface finish of the following:

(a) Arrangement of the system, including the intended method of attachment to the hull and building-in, tunnel geometry, shell openings, method of stiffening, reinforcement, etc.
(b) All torque transmitting components, including the shafting system, impeller and stator if fitted.
(c) Steering components, together with a description and line diagram of the control circuit. This is to include steerable exit water jet nozzles where fitted.
(d) Components of the retractable buckets where these are used for providing astern thrust.
(e) The bearing or bearings absorbing the thrust and supporting the impeller, together with the method of lubrication.
(f) Details of any shafting support or guide vanes used in the water jet system.

2.2.4 Schematic plans of the lubrication and hydraulics required for steering/reversing systems, together with pipe material, relief valves and the working pressures required.

2.3 Calculations and information

2.3.1 Strength calculations based on fatigue considerations incorporating the maximum continuous torque rating and the most 'onerous' operating condition, *see Pt 12, Ch 2, 2.3 Calculations and information 2.3.12*, including any short-term high power operation, and including the effects of mean and fluctuating loads, transitory loadings, residual stress allowances, and stress raisers, for the following components:

(a) Impeller, stator and any bolting arrangements supporting propulsion or steering loads.
(b) Shaft supports and coupling arrangements.
(c) Inlet guide vanes, if fitted.
(d) Steering components, including the lugs of steerable nozzles where fitted.
(e) Retractable buckets and associated mechanisms which are used to provide astern thrust. A calculation of the hydrodynamic transient loads is to be made for each design and is to include the full ahead to full astern condition. The calculation procedure used is to be supported, where possible, with full scale or model test data, or satisfactory service experience, to validate the design method.

2.3.2 Calculations supporting the connection method of the impeller to the shaft including details of the fit, push-up, securing, bolting arrangements, etc. In addition, where lengths of shafts are joined using couplings of the shrunk element type, full particulars of the method of achieving the grip force.

2.3.3 Calculations relating to the design of the shaftline as evidence of compliance with *Pt 11, Ch 2 Shafting Systems*.

2.3.4 Torsional vibration calculations of the complete dynamic system in accordance with the relevant requirements included in *Pt 13, Ch 1 Torsional Vibration*.

2.3.5 Shaft lateral vibration calculations where required by *Pt 13, Ch 3 Lateral Vibration*.

2.3.6 Calculations of the tunnel strength and supporting structure.

2.3.7 A calculation to determine the stresses within the impeller blade.

2.3.8 A calculation of the blade natural frequency for the impeller blades.

2.3.9 A calculation of the relative blade passing frequency between the rotor and stator blades.

2.3.10 The value of the fluctuating stresses during one revolution of the impeller and from transient loadings.

2.3.11 Details of the power/speed range of operation, indicating the maximum continuous torque rating, together with the associated thrusts; this information may be presented in the form of a characteristic curve for the water jet.

2.3.12 The water jet thrust for the assessment of the strength condition being considered is to be as follows:

(a) For ships which are intended to operate predominantly in a free-running condition and at steady service conditions, the water jet thrust is to correspond to the absorption of the maximum continuous shaft power and corresponding revolutions per minute, giving the maximum torque for which the shaft system is approved.
(b) For ships which are designed for several operating conditions, the maximum thrust associated with these conditions and the absorption of the corresponding power, in addition to the maximum continuous powering condition, are to be used in the calculation.
(c) The justification for the thrust selected is to be submitted for consideration in the approval process and this is to include the ship type and the ship speed at the conditions considered.

2.3.13 A justification that the water jet system will meet the self-priming criteria, *see Pt 12, Ch 2, 3.1 General 3.1.6*.

2.3.14 Specifications of materials and NDE procedures for components essential for propulsion and steering operation and, in the case of the impeller and stator, the yield strength and the fatigue characteristics of the material intended for their manufacture.

2.3.15 A detailed weld specification where an impeller has welded blades.

2.3.16 Full details of the means of corrosion protection in the case of carbon or carbon manganese steel shafts. Alternatively, where it is proposed to use composite shafts, details of the connections at flanges, materials, resin, lay-up procedures, quality control procedures and documentary evidence of fatigue endurance strength is to be provided.

2.3.17 Dry impeller mass and polar moment of inertia.

2.3.18 The prime mover type and designation.

2.3.19 Details of the control engineering aspects of the system design in accordance with*Pt 16, Ch 1 Control Engineering Systems*.

2.3.20 The tolerance specification, agreed between the manufacturer and the Shipbuilder or Owner, to which the components of the unit are to be manufactured is to be defined together with a justification.

2.3.21 Details of the water jet's loading reactions together with the positions of application within the hull and is to include the maximum applied thrust, tunnel pressures, moments and forces imposed on the ship.

2.3.22 The water jet unit's rated flow and head.

2.3.23 Where an engineering and safety justification report is required, the following supporting information is to be submitted:

- A Failure Mode and Effects Analysis report (FMEA), *see Pt 12, Ch 2, 2.4 Failure Mode and Effects Analysis (FMEA)*.
- Design standards and assumptions.
- Limiting operating parameters.
- A statement and evidence in respect of the anticipated reliability of any non-duplicated components.

2.3.24 Recommended installation, inspection, maintenance and component replacement procedures. This is to include any in-water engineering procedures where recommended by the water jet manufacturer.

2.3.25 All transient loads which the steering unit is likely to experience from manoeuvring, accelerating, decelerating and the sea conditions.

2.4 Failure Mode and Effects Analysis (FMEA)

2.4.1 An FMEA is to be carried out where a single water jet system is the ship's sole means of propulsion, *see Pt 12, Ch 2, 2.2 Plans to be submitted 2.2.3*. The FMEA is to identify components where a single failure could cause the loss of all propulsion and/or steering capability and the proposed arrangements for preventing and mitigating the effects of such a failure.

2.4.2 The FMEA is to be carried out using the format presented in *Table 22.2.1 Failure Mode and Effects Analysis* of the Rules and Regulations for the Classification of Ships, hereinafter referred to as the Rules for Ships, or an equivalent format that addresses the same reliability issues. Analyses in accordance with IEC 60812 *Analysis for System Reliability – Procedure for Failure Mode and Effects Analysis*, or the IMO Code of Safety for High Speed Craft, 2000, Annex 4 – *Procedures for Failure Mode and Effects Analysis*, would be acceptable.

2.4.3 The FMEA is to be organised in terms of equipment and function. The effects of item failures at a stated level and at higher levels are to be analysed to determine these effects on the system as a whole. Actions for mitigation of the effects of failure are to be determined, *see Pt 12, Ch 2, 2.4 Failure Mode and Effects Analysis (FMEA) 2.4.1*.

2.4.4 The F.M.E.A is to:

(a) identify the equipment or sub-system and mode of operation;
(b) identify potential failure modes and their causes;
(c) evaluate the effects on the system of each failure mode;
(d) identify measures for reducing the risks associated with each failure mode;
(e) identify measures for preventing failure; and
(f) identify trials and testing necessary to prove conclusions.

2.4.5 At sub-system level it is acceptable, for the purposes of these Rules, to consider failure of equipment items and their functions. It is not required that the failure of components within that equipment item be analysed, *see Pt 5, Ch 22, 2.1 General 2.1.5* of the Rules for Ships.

2.4.6 Where a FMEA is used for consideration of systems that depend on software-based functions for control or co-ordination, the analysis is to investigate failure of the functions rather than a specific analysis of the software code itself.

■ *Section 3* Design requirements

3.1 General

3.1.1 The arrangement of water jet units is to be such that the ship can be satisfactorily manoeuvred to a declared performance capability. The operating conditions covered are to include the following:

(a) Maximum continuous shaft power/speed to the impeller in the ahead condition at the declared steering angles and conditions.
(b) Manoeuvring speeds of the impeller shaft and/or reversing mechanism in the ahead and astern direction at the declared steering angles and sea conditions.
(c) The stopping manoeuvre described in *Pt 9, Ch 2, 6.2 Testing*.
(d) Astern running conditions for the craft.

3.1.2 The mean loadings are those loadings induced by the water jet absorbing the mean torque supplied by the prime mover.

3.1.3 Fluctuating loads are defined as those loads which occur during one revolution of the impeller due to cyclic variations. For example, the spatial flow variations and torsional vibration at nominally steady state operating conditions.

3.1.4 Transient loads are defined as those loadings resulting from acceleration and deceleration of the ship, manoeuvring, seaway conditions and other similar forms of loading. This also includes any significant back-pressure effects developed from the operation of the reversing bucket, if fitted.

3.1.5 To ensure self-priming of the water jet unit, the shaft centreline of the unit is to be lower than the light draught static waterline of the ship. In cases where this is either impracticable or undesirable, the distance of the impeller shaft centreline above the ship's light draught waterline is to be less than or equal to 10 per cent of the pump inlet diameter.

3.1.6 Provision is to be made to allow for the in-service visual inspection of the complete blade surfaces of both the impeller and stator blades using either a direct visual or borescope inspection technique.

3.2 Shaftline

3.2.1 The diameter of the shaftline components are to comply with *Pt 11, Ch 2 Shafting Systems*. For calculation purposes the shaft carrying the impeller is to be taken as equivalent to a screwshaft.

3.2.2 Where it is proposed to use carbon or carbon manganese steel shafts which may be in contact with seawater, these are to be protected.

3.2.3 The diameter of unprotected screwshafts of corrosion- resistant material is not to be less than that given in *Pt 11, Ch 2, 4.4 Screwshafts and tube shafts 4.4.7*.

3.2.4 The use of composite shafts is permitted, *see Pt 12, Ch 2, 2.3 Calculations and information 2.3.16*.

3.2.5 Where lengths of shafts are joined using couplings of the shrunk element type, a factor of safety, based upon the mean plus the vibratory and transient torques, against slippage of 2,0 is to be achieved for couplings which are located inboard and 2,5 for couplings which are located outboard.

3.2.6 Where shaftline components are bolted together, the design of the bolted connection should demonstrate a factor of safety of 1,5 when considered in the context of the mean, fluctuating and transitory loadings.

3.2.7 If a keyed fitting of the impeller to the shaft is contemplated, then the requirements of *Pt 11, Ch 2, 4.12 Keys and keyways for propeller connections* are to be satisfied.

3.2.8 Where it is proposed to fit a keyless impeller, the fitting is to comply with the requirements of*Pt 12, Ch 1, 4.2 Interference fit of keyless propellers*, as applicable, excluding the requirements for Ice Class. Use of the words ‘propeller’ and ‘screwshaft’ are to be taken as meaning ‘impeller’ and ‘impellershaft’ respectively.

3.3 Shaft support system and guide vanes

3.3.1 In cases where the shaft requires support from the tunnel walls ahead of the impeller or, alternatively, where guide vanes are required to assist the flow around a bend in the ducting system, the supports or guide vanes are to be suitably aligned to the flow and have suitably rounded leading and trailing edges or be of an aerofoil section.

3.3.2 In general, the fillet radius should be greater than or equal to the maximum thickness of the vane or support at that location. Smaller radii may be considered, for which the results of an approved measurement programme or calculation procedure are to be submitted. In all cases, a factor of safety of at least 1,5 is to be demonstrated for the maximum designed operating conditions.

3.3.3 A facility for the inspection of the supports or guide vanes is to be provided, which will allow either direct visual or borescope inspection of these components and their transition to other members.

3.4 Impeller

3.4.1 A calculation to determine the stresses within the impeller blades is to be carried out which takes into account the mean blade loading, fluctuating loadings, transient loads and centrifugal force. The computations may be accomplished by either classical methods or numerical analysis. Designs of water jet systems which have been based on a combination of computational fluid dynamics and finite element methods will be considered. However, it will be necessary to demonstrate to the satisfaction of LR that the formulation of the methods used has been correlated with previous full scale measurement or other calculation experience.

3.4.2 For the purposes of the calculation required by this sub-Section, the fluctuating stresses during one revolution of the impeller is to be taken as 20 per cent of the maximum mean stress, and the stresses from transient loadings are to be taken as 15 per cent of the hydrodynamic mean stress, unless otherwise specified by the designer.

3.4.3 The fatigue assessment of the impeller blades is to be based on the stress in the root sections, excluding the influence of the blade root fillets. This assessment is to include the following components:

- the maximum stresses derived from the mean loading, including both the hydrodynamic and centrifugal components;
- the amplitude of the fluctuating stresses during one revolution of the impeller;
- the stresses derived from transient loading and an allowance for any residual stresses in the material.

It is permissible to combine the variable components of stress in a linear fatigue damage accumulation assessment procedure. A factor of safety of at least 1,5 against fatigue failure is to be demonstrated for the maximum continuous rating condition or any other more onerous condition, *see Pt 12, Ch 2, 3.1 General 3.1.1*.

3.4.4 In general, the fillet radius is to be greater than the maximum thickness of the impeller blade at that location. Composite radiused fillets or elliptical fillets which provide an improved stress concentration factor are preferred.

3.4.5 Where an impeller has bolted-on blades, consideration is to be given to the distribution of stress in the palms of the blade and in the hub and bolting arrangements.

3.4.6 Where an impeller has welded blades, the welds are to be of the full penetration type or of equivalent strength. Where laser welding is to be used, details are to be submitted for consideration.

3.4.7 The blades are to be provided with hydrodynamically faired leading and trailing edges which may be either of simple radius or of a more complex aerofoil edge form. The tip clearance, whilst being kept to a minimum for hydrodynamic purposes, is to be sufficient to allow for any transient vibrational behaviour, axial shaft movement or differential thermal expansion.

3.4.8 A calculation of the blade natural frequency for the impeller blades is to be undertaken. The fundamental natural frequency in water of the blade is to be shown to lie outside any expected excitation frequencies within a speed range of the water jet unit and up to 10 per cent above the maximum impeller speed.

3.5 Stator

3.5.1 The stator blades, where fitted, are to be designed to be capable of withstanding the combined hydrodynamic mean, fluctuating, transient and mechanical loads, including any loads transmitted via shaft bearings, developed by the unit and reacted through the blades when the impeller is absorbing full power. Consideration is to be given to situations when the vessel is either free running or in a condition specified by *Pt 12, Ch 2, 3.1 General 3.1.1* or undergoing stopping, accelerating or decelerating manoeuvres. A factor of safety against mechanical failure by yielding of the blades of 1,5 is to be demonstrated.

3.5.2 In general, the fillet radius is to be greater than the maximum thickness of the blade at that location. Composite radiused fillets or elliptical fillets which provide improved stress concentration factors are preferred.

3.5.3 If the stator ring comprises a segmented assembly, then consideration is also to be given to the distribution of stress in the various adjacent members of the overall assembly.

3.5.4 A calculation of the relative blade passing frequency between the rotor and stator blades is to demonstrate that this does not coincide with the natural frequency of the stator blades over the speed range of the waterjet unit and up to 10 per cent above maximum impeller speed.

3.5.5 The stator blades are to be provided with hydrodynamically faired leading edges which may have either a simple radius or a more complex aerofoil edge form.

3.5.6 Where the stator blading assembly forms part of the nozzle, the requirements of *Pt 12, Ch 2, 3.7 Nozzle/steering arrangements* are to be considered in association with those for the stator assembly.

3.6 Tunnel and securing arrangements

3.6.1 The tunnel is to be adequately supported, framed and fully integrated into the hull structure. The critical locations and integrity of the supports and framing are to be as specified in the FMEA and agreed by the Shipbuilder and LR.

3.6.2 The tunnel and supporting structure scantlings are to be not less than the Rule requirements for the surrounding structure. The strength of the hull structure in way of tunnel(s) is to be maintained. The structure is to be adequately reinforced and compensated as necessary. All openings are to be suitably reinforced and have radiused corners.

3.6.3 Consideration is to be given to providing the inlet to the tunnel with a suitable guard to prevent the ingress of large objects into the rotodynamic machinery. The dimensions of this guard, if fitted, are to strike a balance between undue efficiency loss due to flow restriction and viscous losses, the size of object allowed to pass and the susceptibility to clog with weed and other flow-restricting matter.

3.6.4 The inlet profile of the tunnel is to be designed so as to provide a smooth uptake of the water over the range of vessel operating trims and avoid significant separation and/or cavitation of the flow which may then pass downstream into the rotating machinery.

3.6.5 Design consideration is to take account of pressures which could develop as a result of a duct blockage as well as in relation to the axial location of rotating parts.

3.6.6 The strength of the tunnel and supporting structure are to be examined by direct calculation procedures.

3.7 Nozzle/steering arrangements

3.7.1 In general, the steering systems and components are to comply with the requirements of*Pt 14, Ch 1 Steering Systems*.

3.7.2 Nozzles can be either of a fixed or steerable form. The design of the nozzle is to take into account fully the change in pressure distribution along its inner surface together with the other mechanical loads (e.g. stator assembly loads) and transient loads caused by the flow directing attachments which may be reacted through the body of the nozzle. In this analysis, the changes to the pressure distribution caused by transient manoeuvres are to be considered.

3.7.3 In addition to the requirements of *Pt 14, Ch 1 Steering Systems*, the steering mechanism and bucket are to be capable of maintaining the manoeuvrability of the ship in terms of turning circle, zig-zag and stopping requirements within the limits defined

by IMO *Resolution MSC.137(76) - Standards for Ship Manoeuvrability - (adopted on 4 December 2002)*, Standards for Ship Manoeuvrability.

3.7.4 Consideration is to be given to all transient loads which the steering unit is likely to experience from manoeuvring, accelerating, decelerating and the sea conditions.

3.7.5 The nozzle/bucket is to be given mechanical protection by the Shipbuilder from other impact damage such as collision.

3.8 Bolts

3.8.1 Detailed consideration and analysis is to be given to essential bolting arrangements in critical locations as specified in the FMEA and where indicated by the Manufacturer or Shipbuilder and agreed by LR. These are to include bolts used in the securing of blades or guide vanes, assembly of the unit in the ship and any conduit components.

■ *Section 4*
Piping systems

4.1 General

4.1.1 The piping systems for a water jet unit are to comply with the general requirements of *Pt 15, Ch 3 Machinery Piping Systems*.

4.1.2 Lubricating and hydraulic oil systems and standby arrangements are to comply with the requirements of*Pt 15, Ch 3 Machinery Piping Systems*; in addition, steering hydraulic systems are to comply with the applicable requirements of*Pt 14, Ch 1 Steering Systems*.

■ *Section 5*
Control and monitoring

5.1 General

5.1.1 In addition to this Section, the control engineering systems are to comply with *Pt 16, Ch 1 Control Engineering Systems*.

5.1.2 Steering control for the water jet is to be provided at the ship's normal conning stations.

5.1.3 For water jets used as the only means of propulsion and steering, a standby or alternative power source for the actuating device, that controls the angular position and/or the reversing angle, is to be provided. Automatic start of the standby pump supplying hydraulic power for steering and reversing is to be provided.

5.1.4 Means are to be provided at each control station to stop each water jet.

5.2 Monitoring and alarms

5.2.1 In addition to the requirements of *Pt 14, Ch 1 Steering Systems*, alarms and monitoring requirements are indicated in *Pt 12, Ch 2, 5.2 Monitoring and alarms 5.2.2* and *Table 2.5.1 Alarms*.

Table 2.5.1 Alarms

Item	Alarm	Note
Hydraulic system pressure	Low	-
Hydraulic oil supply tank level	Low	-
Hydraulic oil temperature	High	Where an oil cooler is fitted
Lubricating oil temperature	High	
Lubricating oil pressure	Low	In forced lubrication systems

Lubricating oil tank level	Low	Where a tank is provided
Ratio of jet rpm/vessel speed	High	Only if installed power per jet > 4 MW
Control system failure	Fault	Includes follow-up failure of steering or reversing system
Control system power supply	Failure	

5.2.2 An indication of the angular position of the nozzle is to be provided at each station from which it is possible to control the direction of thrust from the units.

5.2.3 An indication of both the required and actual reversing bucket position is to be provided at each station from which it is possible to control the reversal of thrust.

5.2.4 All alarms associated with water jet unit faults are to be indicated individually at the control stations and in accordance with the alarm system specified by *Pt 16, Ch 1 Control Engineering Systems*.

■ *Section 6* Electrical systems

6.1 Installation and distribution arrangements

6.1.1 The electrical installation is to comply with the relevant sections of *Pt 16, Ch 2 Electrical Engineering*.

6.1.2 Water jet auxiliaries and controls are to be served by individual circuits. Services that are duplicated are to be separated throughout their length as widely as practicable and without the use of common feeders, transformers, converters, protective devices or control circuits.

■ *Section 7* Inspection, testing and fitting of water jets

7.1 General

7.1.1 The finished impeller is to be statically balanced on completion of the manufacturing process and meet the requirements of ISO 1940 or an alternative standard acceptable to LR. In the case where the blade tip speed is greater than 60 m/s, dynamic balancing is required unless otherwise agreed by the manufacturer and LR.

7.1.2 The following tests, markings and inspections are to be carried out in the presence of the Surveyor:

(a) The balancing of the impeller or the blades.
(b) Non-destructive examination of the impeller blades and the principal component parts of the propulsion system: for austenitic stainless steels, *see Ch 4, 8 Stainless steel castings*, and for aluminium alloys, *see Ch 8, 3 Aluminium alloy castings*, of the Rules for Materials.
(c) The quality of the fit of the impeller boss on the shaft taper.
(d) The fitting of the impeller to the shaft and its subsequent functional testing.
(e) The finished surfaces of the impeller boss, hub, conical bores, fillets, cones and blade surfaces are to be shown to conform to the tolerances specified on the impeller drawing.

7.1.3 Bolts and nuts in critical locations, as specified in the FMEA and where indicated by the manufacturer or Shipbuilder and agreed by LR, are to be equipped with adequate securing arrangements to the satisfaction of the LR Surveyor.

7.2 Shop tests and installation of water jet systems

7.2.1 The completed water jet unit is to undergo a tightness test in which an internal hydrostatic pressure of 1,5 bar above the maximum working pressure of the unit is to be applied.

7.2.2 In cases where the impeller is fitted to the shaft using an interference fit, the bedding of the impeller with the shaft is to be demonstrated in the shop to the satisfaction of the LR Surveyor. Sufficient time is to be allowed for the temperature of the components to equalise before bedding. A contact marking between the bore of the impeller boss and the shaft surface of better than 80 per cent is to be demonstrated when the contact marking ink is spread thinly on the surface of the shaft. Alternative means for demonstrating the bedding of the impeller will be considered.

7.2.3 Means are to be provided to indicate the relative axial position of the impeller boss on the shaft. Permanent reference marks are to be made on the impeller boss, shaft and any nut to indicate angular and axial positioning of the impeller. Care is to be taken in marking the inboard end of the shaft taper to minimise stress-raising effects.

7.2.4 A copy of the fitting curve relative to temperature and means for determining any subsequent movement are to be placed on board.

7.2.5 The impeller running clearances are to be checked following the installation of the unit in the ship.

7.2.6 The thrust bearing clearances in the water jet system are to be verified against the required design values. This is to be done following the installation of the unit in the ship.

7.2.7 The piping systems are to be adequately flushed in accordance with the Manufacturer's recommendations and the final levels of contamination recorded. Similarly, pressure testing of the piping systems is to comply with*Pt 15, Ch 1 Piping Design Requirements*.

7.3 Sea trial requirements

7.3.1 The following requirements are to be complied with:

- *Pt 9, Ch 2, 6.2 Testing* for sea trials.
- *Pt 14, Ch 1, 4.4 Performance* for steering trials.

In addition, the general design capability specified in 3.1.1 is to be demonstrated to the Surveyor's satisfaction.

7.3.2 The control systems relating to the correct functioning of the water jet is to be the subject of harbour and then sea trials. Demonstration of the requirements of*Pt 16, Ch 1 Control Engineering Systems* is required and the design combinations of control functions are to be undertaken during the trials programme.

7.3.3 On sea trials and under free running conditions, the relationship between ship speed and impeller rotational speed is to be verified against the water jet's design basis.

7.3.4 Any trials and testing identified from the FMEA report, *see Pt 12, Ch 2, 2.4 Failure Mode and Effects Analysis (FMEA)*, are to be carried out.

■ *Section 8*
Installation, maintenance and replacement

8.1 General

8.1.1 All water jet system propulsion units are to be provided with a copy of the manufacturer's installation and maintenance manual that is pertinent to the actual equipment. *See Pt 12, Ch 2, 2.3 Calculations and information 2.3.24*.

8.1.2 The manual required by *Pt 12, Ch 2, 8.1 General 8.1.1* is to be placed on board and is to contain the following information:

(a) Description of the water jet propulsion system with details of function and design operating limits. This is also to include details of support systems such as lubrication, cooling and condition monitoring arrangements.
(b) Identification of all components together with details of any that have a defined maximum operating life.
(c) Instructions for installation of the system on board ship with details of any required specialised equipment.
(d) Instructions for commissioning at initial installation and following maintenance.
(e) Maintenance and service instructions to include inspection/renewal of bearings and sealing arrangements. This is also to include component fitting procedures, clearance measurements and lubricating oil treatment where applicable.
(f) Actions required in the event of fault/failure conditions being detected.
(g) Precautions to be taken by personnel working during installation and maintenance.

Section

■ *Section 1* General requirements

1.1 Application

1.1.1 This Chapter is to be read in conjunction with the General Requirements for Machinery in *Pt 9 General Requirements for Machinery*.

1.1.2 This Chapter gives requirements for fixed or steerable thruster units (azimuth thrusters) which are used for propulsion and steering, and also applies to transverse propulsion (tunnel) thrusters which are an aid to manoeuvring.

1.1.3 In this Chapter where the dimensions of any particular component are determined from shaft power, *P*, in kW, and revolutions per minute, *R*, the values to be used are those defined in *Pt 9 General Requirements for Machinery*.

1.2 Redundancy

1.2.1 A minimum of two azimuth thruster units are to be provided where these form the sole means of propulsion. Where a single azimuth thruster installation is proposed, it will be subject to consideration, taking into account the proposed restricted area notation.

1.2.2 The failure of one azimuth thruster unit or its control system is not to render any other thruster inoperative.

1.3 Inclination of craft

1.3.1 Thruster units are to operate satisfactorily under the conditions as shown in *Pt 9 General Requirements for Machinery*.

1.4 Condition Monitoring

1.4.1 Where Thruster Condition Monitoring (**ThCM)** ShipRight descriptive note has been requested, refer to *ShipRight ProcedureMachinery Planned Maintenance and Condition Monitoring*, Section 8.

■ *Section 2* Particulars to be submitted

2.1 Submission of information

2.1.1 At least three copies of the following plans are to be submitted.

2.1.2 **Fixed/Azimuth propulsion thrusters.**

(a) A general arrangement sectional assembly plan showing all the connections of the torque transmitting components from the prime mover to the propeller, together with the azimuthing mechanism and, if a nozzle is provided, the nozzle ring structure and nozzle support struts.
(b) Detailed and dimensional plans of the individual torque transmitting components.
(c) Schematic plans of lubricating and hydraulic systems, together with pipe material, relief valves and working pressures.

2.1.3 **Tunnel thrusters.**

(a) Structural assembly plan including connections to tunnel.

2.2 Calculations and specifications

2.2.1 At least three copies of the following information are to be submitted.

2.2.2 **Fixed/Azimuth propulsion thrusters.**

(a) Thruster prime mover type and operational power/speed envelope.
(b) Rating and type of motor for the azimuthing mechanism (e.g. type - hydraulic or electric).
(c) Gearing calculations for the azimuthing mechanism which is to be designed to a recognised National Standard.
(d) Bearing specifications.
(e) Details of control engineering aspects in accordance with *Pt 16, Ch 1 Control Engineering Systems*.
(f) Calculations indicating suitability of components for short term high power operation, where applicable. *See Pt 9 General Requirements for Machinery*.
(g) Where carried out in accordance with *Pt 9 General Requirements for Machinery*, a fatigue strength analysis of components indicating a factor of safety of 1,5 at the design loads, based on a suitable fatigue failure criteria.

2.2.3 **Tunnel thrusters.**

(a) Specification for materials of gears, shafts, couplings and propeller, stock and struts.

■ *Section 3* Materials

3.1 Azimuth thrusters

3.1.1 The materials used in the construction are to be manufactured and tested in accordance with the *Rules for the Manufacture, Testing and Certification of Materials, July 2021* (hereinafter referred to as the Rules for Materials).

■ *Section 4* Design and construction

4.1 General

4.1.1 The arrangement of all types of thrusters is to be such that the craft can be manoeuvred in accordance with the design specifications.

4.1.2 The requirements associated with the structural and watertight integrity and the installation arrangement are to be in accordance with *Pt 3, Ch 3 Control Systems*.

4.1.3 In addition to the requirements of this Section reference is to be made to:

(a) Main transmission gearing (*Pt 11, Ch 1 Gearing*).
(b) Main transmission shafting (*Pt 11, Ch 2 Shafting Systems*).
(c) Propeller (*Pt 12, Ch 1 Propellers*).
(d) Torsional vibration (*Pt 13, Ch 1 Torsional Vibration*).
(e) Lateral vibration for shafting systems which include cardan shafts (*Pt 13, Ch 3 Lateral Vibration*).

4.2 Azimuth thrusters

4.2.1 The following requirements are to be complied with:

(a) The azimuthing mechanism is to be capable of a maximum rotational speed of not less than 1,5 rev/min.

(b) Gearing for the azimuthing mechanism is to be designed to a recognised National Standard. The design is to consider both static (< 10^3 cycles) and dynamic loading conditions.

(c) Under dynamic operating conditions, the gear is to be considered for

- (i) design maximum dynamic duty steering torque,
- (ii) variable loading, where applicable. A spectrum (duty) factor may be used. The load spectrum value is to be derived using load measurements of similar units, where possible.

(d) Under a static duty (< 10^3 load cycles) steering torque, which should be not less than M_{T}, as defined in *Pt 12, Ch 3, 4.3 Azimuth thrusters with a nozzle 4.3.1*.

(e) The following minimum factor of safety values are to be achieved:

Surface Stress S_{Hmin} = 1,0.

Bending Stress S_{Fmin} = 1,5.

(f) For hydraulic pressure retaining parts and load bearing components, *see also Pt 14 Steering Systems*.

4.3 Azimuth thrusters with a nozzle

4.3.1 Where the propeller is contained within a nozzle, the equivalent rudder stock diameter in way of tiller, used in *Table 1.4.1 Connection of tiller to stock* in Pt 14, Ch 1 is to be determined as follows:

$$d_{su} = 26,03\sqrt[3]{(V+3)^2 A_N X_{PF}} \text{ mm}$$

where

V = maximum service speed, in knots, which the craft is designed to maintain under thruster operation

A_N = projected nozzle area, in m^2, and is equal to the length of the nozzle multiplied by the mean external vertical height of the nozzle

X_{PF} = horizontal distance from the centreline of the steering tube to the centre of pressure, in metres. The position of the centre of pressure is determined from *Table 3.2.5 Position of centre of pressure* .

The corresponding maximum turning moment, M_{T}, is to be determined as follows:

$$M_T = 11,1 \times d_{su}^3 \text{ Nmm}$$

4.3.2 In addition to the requirements of *Pt 3 General Requirements and Constructional Arrangements* the scantlings of the nozzle stock or steering tube are to be such that the section modulus Z against transverse bending at any section x-x is not less than:

$$Z = 1,73\sqrt{(V+3)^4 A_N^2 X_{PF}^2 + \frac{a^2}{4} T_M^2 10^4} \text{ cm}^3$$

where

a = dimension, in metres, as shown in *Figure 3.4.1 Azimuth thruster*

T_M = maximum thrust of the thruster unit, in tonnes

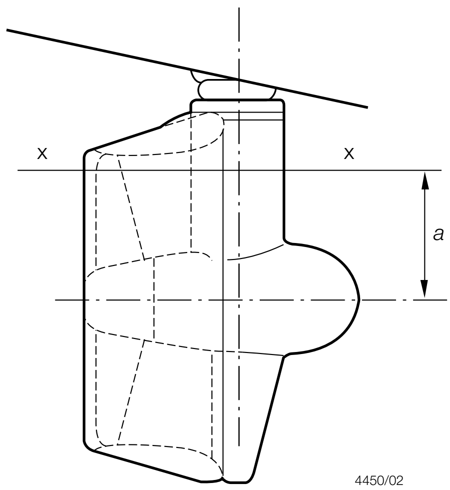


Figure 3.4.1 Azimuth thruster

4.3.3 The scantlings of nozzle connections or struts will be specially considered. In the case of certain high powered craft, direct calculation may be required.

4.3.4 Where the propeller is not contained in a nozzle, the scantlings in way of the tiller will be subject to special consideration.

■ *Section 5* Piping systems

5.1 General

5.1.1 The piping system for azimuth thrusters is to comply with the general design requirements given in *Pt 15, Ch 1 Piping Design Requirements*.

5.1.2 The specific requirements for lubricating/hydraulic oil systems and standby arrangements are given in *Pt 15, Ch 3 Machinery Piping Systems*.

5.2 Azimuth thruster

5.2.1 The hydraulic power operating systems for each azimuth thruster are to be provided with the following:

(a) arrangements to maintain the cleanliness of the hydraulic fluid, taking into consideration the type and design of the hydraulic system,

(b) a fixed storage tank having sufficient capacity to recharge at least one azimuth power actuating system including the reservoir. The piping from the storage tank is to be permanent and arranged in such a manner as to allow recharging from within the thruster space.

5.2.2 Where the lubricating oil for the azimuth thrusters is circulated under pressure, provision is to be made for the efficient filtration of the oil. The filters are to be capable of being cleaned without stopping the thruster or reducing the supply of filtered oil.

Section 6
Control and monitoring

6.1 General

6.1.1 Except where indicated in this Section the control engineering systems are to be in accordance with *Pt 16, Ch 1 Control Engineering Systems*.

6.1.2 Azimuthing control for azimuth thruster(s) and propeller pitch control for azimuth and/or tunnel thruster(s) are to be provided from the navigating bridge, the main machinery control station and locally.

6.1.3 Means are to be provided at the remote control station(s) to stop each azimuth or tunnel thruster unit.

6.2 Monitoring and alarms

6.2.1 Alarms and monitoring requirements are indicated in *Pt 12, Ch 3, 6.2 Monitoring and alarms 6.2.2*, *Pt 12, Ch 3, 6.2 Monitoring and alarms 6.2.3* and *Table 3.6.1 Alarms*.

Table 3.6.1 Alarms

Item	Alarm	Note
Thruster, azimuth or tunnel	-	Indicators, *see Pt 12, Ch 3, 6.2 Monitoring and alarms 6.2.2*
Azimuthing motor	Power failure, single phase	Also running indication on bridge and at machinery control station
Propeller pitch motor	Power failure	Also running indication on bridge and at machinery control station
Propulsion motor	Overload, power failure	Also running indication on bridge and at machinery control station
Control system	Failure	
Hydraulic oil supply tank level	Low	
Hydraulic oil system pressure	Low	
Hydraulic oil system temperature	High	Where oil cooler is fitted
Hydraulic oil filters differential pressure	High	Where oil filters are fitted
Lubricating oil supply pressure	Low	If separate forced lubrication

6.2.2 An indication of the angular position of the azimuth thruster(s) and the propeller pitch position for azimuth and/or tunnel thruster(s) are to be provided at each station from which it is possible to control the direction of thrust or the pitch.

6.2.3 All alarms associated with thruster unit faults are to be indicated individually on the navigating bridge and in accordance with the alarm system specified by *Pt 16 Control and Electrical Engineering*.

Section 7
Electrical systems

7.1 General

7.1.1 The electrical installation is to be designed, constructed and installed in accordance with the requirements of *Pt 16 Control and Electrical Engineering*.

7.2 Emergency power for steering systems and drives

7.2.1 For high speed craft, in the event of total power failure, either:

(a) emergency power for steering systems/drives is to be restored automatically within five seconds. To achieve this an interim fast acting system may be required to come into operation until such time as the auxiliary/emergency power source comes on line. (Note: starting arrangements are to comply with the requirements relating to starting arrangements of emergency generators), or
(b) means are to be provided to bring the craft to a safe condition.

7.3 Circuits

7.3.1 Azimuth thruster auxiliaries and controls are to be served by individual circuits. Services that are duplicated are to be separated throughout their length as widely as is practicable and without the use of common feeders, transformers, converters, protective devices or control circuits.

■ *Section 8* Requirements for craft which are not required to comply with the HSC Code

8.1 Design and installation

8.1.1 Tunnel thrusters on service craft less than 24 m and yachts which are not essential for steering and manoeurving do not have to comply with the design requirements of this Chapter.

8.1.2 The installation of such thrusters is to be such as to maintain the structural and watertight integrity of the craft.

8.2 Control and monitoring

8.2.1 Alarms and monitoring requirements of *Table 3.6.1 Alarms* are not required for service craft of less than 24 m.

Contents

Section

■ *Section 1*
General requirements

1.1 Application

1.1.1 This Section is to be read in conjunction with the requirements of *Pt 9 General Requirements for Machinery*, *Pt 10 Prime Movers*, *Pt 11 Transmission Systems* and *Pt 12 Propulsion Devices*.

1.1.2 Unless otherwise advised, it is the responsibility of the Builder as main contractor to ensure, in co-operation with the Enginebuilders, that the information required by this Chapter is prepared and submitted.

1.1.3 The requirements of this Chapter are applicable to the following systems:

(a) Main propulsion systems formed by oil engines, turbines or electric motors, directly driven or geared to the shafting.
(b) Machinery driven at constant speed by oil engines, developing 110 kW and over, for essential auxiliary services including generator sets which are the source of power for main electric propulsion motors.

1.2 Power ratings

1.2.1 In this Chapter where shaft power, P, in kW, and revolutions per minute, R, are referred to, the values to be used are those defined in *Pt 9 General Requirements for Machinery*.

1.3 Basic requirements

1.3.1 System designs are to take account of the potential effects of engine and component malfunction and variability in characteristic values.

1.3.2 Where torques, stresses or amplitudes are found to exceed the limits for continuous operation, restrictions in speed and/or power will be imposed.

■ *Section 2*
Details to be submitted

2.1 Particulars to be submitted

2.1.1 Torsional vibration calculations, including an analysis of the vibratory torques and stresses for the full dynamic system.

2.1.2 Particulars of the division of power and utilisation, throughout the speed range, for turbines, multi-engine or other combined power installations, and those with power take-off systems. For multi-engined installations, special considerations associated with the possible variations in the mode of operation and phasing of engines.

2.1.3 Enginebuilders' harmonic torque data used in the torsional vibration calculations, *see Pt 13, Ch 1, 2.2 Scope of calculations 2.2.3*.

2.1.4 Details of operating conditions encountered in service for prolonged periods, e.g. idling speed, trawling revolutions per minute, combinatory characteristics for installations equipped with controllable pitch propellers.

2.1.5 Details, obtained from the manufacturers, of the principal characteristics of machinery components such as dampers and couplings, confirming their capability to withstand the effects of vibratory loading including, where appropriate, heat dissipation. Evidence that the data which is used to represent the characteristics of components, which has been quoted from other sources, is supported by a programme of physical measurement and control.

2.1.6 Where installations include electric motors, generators or non-integral pumps, drawings showing the principal dimensions of the shaft, together with the manufacturer's estimates of mass moment of inertia for the rotating parts.

2.1.7 Details of vibration or performance monitoring proposals where required.

2.2 Scope of calculations

2.2.1 Calculations are to be carried out, by recognised techniques, for the full dynamic system formed by the oil engines, turbines, motors, generators, flexible couplings, gearing, shafting and propeller, where applicable, including all branches.

2.2.2 Calculations are to give due consideration to the potential deviation in values used to represent component characteristics due to manufacturing/service variability.

2.2.3 The calculations carried out on oil engine systems are to be based on the Enginebuilders' harmonic torque data. (On request, Lloyd's Register (hereinafter referred to as 'LR') can provide a table of generalised harmonic torque components for use where appropriate.) The calculations are to take account of the effects of engine malfunction commonly experienced in service, such as a cylinder not firing (i.e. no injection but with compression), giving rise to the highest torsional vibration stresses in the shafting. Calculations are also to take account of a degree of imbalance between cylinders, characteristic of the normal operation of an engine under service conditions.

2.2.4 Whilst limits for torsional vibration stress in crankshafts are no longer stated explicitly, calculations are to include estimates of crankshaft stress at all designated operating/service speeds, as well as at any major critical speed.

2.2.5 Calculations are to take into account the possible effects of excitation from propeller rotation. Where the system shows some sensitivity to this phenomenon, propeller makers' data should be used as a basis for calculation, and submitted.

2.2.6 Where the torsional stiffness of flexible couplings varies with torque, frequency or speed, calculations should be representative of the appropriate range of effective dynamic stiffness.

■ *Section 3*
Design

3.1 Symbols and definitions

3.1.1 The symbols used in this Section are defined as follows:

d = minimum diameter of shaft considered, in mm

d_{i} = diameter of internal bore, in mm

k = the factor used in determining minimum shaft diameter, defined in *Pt 11, Ch 2, 4.2 Intermediate shafts 4.2.1* and *Pt 11, Ch 2, 4.4 Screwshafts and tube shafts 4.4.3*

r = ratio N/N_{s} or $N_{\mathrm{c}}/N_{\mathrm{s}}$ whichever is applicable

C_{d} = a size factor defined as $0{,}35 + 0{,}93d^{-0{,}2}$

C_{k} = a factor for different shaft design features, *see Table 1.3.1 C_k factors*

N = engine speed, in rev/min

N_{c} = critical speed, in rev/min

N_s = maximum continuous engine speed, in rev/min, or, in the case of constant speed generating sets, the full load speed, in rev/min

Q_s = rated full load mean torque

σ_u = specified minimum tensile strength of the shaft material, in N/mm^2

τ_c = maximum value of the vibration stress for continuous running at or below the maximum speed, in N/mm^2

τ_t = permissible stress due to torsional vibrations for transient operation, in N/mm^2

e = slot width, in mm

l = slot length, in mm.

3.1.2 Alternating torsional vibration stresses are to be based on half-range amplitudes of stress resulting from the alternating torque (which is superimposed on the mean torque) representing the synthesis of all harmonic orders present.

3.1.3 All vibration stress limits relate to the synthesis or measurement of total nominal torsional stress and are to be based on the plain section of the shafting neglecting stress raisers.

Table 1.3.1 C_k factors

Intermediate shafts with	
Integral coupling flange and straight sections	1,0
Shrink fit coupling	1,0
Keyway, tapered connection	0,60
Keyway, cylindrical connection	0,45
Radial hole	0,50
Longitudinal slot	0,30 (*see Pt 13, Ch 1, 3.1 Symbols and definitions 3.1.4*)
Thrust shafts external to engines	
On both sides of thrust collar	0,85
In way of axial bearing where a roller bearing is used as a thrust bearing	0,85
Propeller shafts	
Flange mounted or keyless taper fitted propellers	0,55
Key fitted propellers	0,55
Between forward end of aft most bearing and forward sterntube seal	0,80
Note The determination of C_k factors for shafts other than shown in this Table will be specially considered by LR.	

3.1.4 For a longitudinal slot, C_k = 0,3 is applicable within the dimension limitations given in *Pt 11, Ch 2, 4.2 Intermediate shafts 4.2.7*. If the slot dimensions are outside these limitations, or if the use of another C_k is desired, the actual stress concentration factor (*scf*) is to be documented or determined from *Pt 13, Ch 1, 3.1 Symbols and definitions 3.1.5* or by direct application of FE calculation, in which case:

$$C_k = \frac{1,45}{scf}$$

Note that the *scf* is defined as the ratio between the maximum local principal stress and $\sqrt{3}$ times the nominal torsional stress (determined for the bored shaft without slots).

3.1.5 **Stress concentration factor of slots**. The stress concentration factor (*scf*) at the ends of slots can be determined by means of the following empirical formulae:

$$scf = \alpha_{\mathrm{t(hole)}} + 0,8\frac{\frac{(I-e)}{d}}{\sqrt{\left(1-\frac{\mathrm{d_i}}{\mathrm{d}}\right)\frac{e}{d}}}$$

This formula applies to:

- Slots at 120 or 180 or 360 degrees apart.
- Slots with semicircular ends. A multi-radii slot end can reduce the local stresses, but this is not included in this empirical formula.
- Slots with no edge rounding (except chamfering), as any edge rounding increases the *scf* slightly.

$\alpha_{\mathrm{t(hole)}}$ = represents the stress concentration of radial holes and can be determined as:

$\alpha_{\mathrm{t(hole)}}$ = $2,3-3\frac{e}{d}+15\left(\frac{e}{d}\right)^2+10\left(\frac{e}{d}\right)^2\left(\frac{d_i}{d}\right)^2$

where, in this context, *e* = hole diameter, in mm (this is independent of slot width)

or simplified to $\alpha_{\mathrm{t(hole)}}$ = 2,3.

3.2 Limiting stress in propulsion shafting

3.2.1 The following stress limits apply to intermediate shafts, thrust shafts and to screwshafts fully protected from seawater. For screwshafts, the limits apply to the portions of the screwshaft as defined in *Pt 11, Ch 2, 4.4 Screwshafts and tube shafts*

3.2.2 In the case of unprotected screwshafts, special consideration will be given.

3.2.3 In no part of the propulsion shafting system may the alternating torsional vibration stresses exceed the values of τ_c for continuous operation, and τ_t for transient running, given by the following formulae:

For *r* <0,9:

$$\tau_{\mathrm{c}} = \frac{\sigma_{\mathrm{u}}+160}{18}C_{\mathrm{k}}C_{\mathrm{d}}\left(3-2r^2\right)\ \mathrm{N/mm^2}$$

and where *r* < 0,8

$$\tau_{\mathrm{t}} = \pm 1,7\,\tau_{\mathrm{c}}\frac{1}{\sqrt{C_{\mathrm{k}}}}\quad \mathrm{N/mm^2}$$

For 0,9 ≤*r* ≤ 1,05:

$$\tau_{\mathrm{c}} = \frac{\sigma_{\mathrm{u}}+160}{18}C_{\mathrm{k}}C_{\mathrm{d}}\ 1,38\ \ \mathrm{N/mm^2}$$

3.2.4 In general, the tensile strength of the steel used is to comply with the requirements of *Pt 11, Ch 2 Shafting Systems*. For the calculation of the permissible limits of stresses due to torsional vibration, σ_u is not to be taken as more than 800 N/mm^2 in the case of intermediate shafts and 600 N/mm^2 in the case of thrust and propeller shafts unless, for intermediate shafts only, it is verified that the materials exhibit a similar fatigue life to conventional steels through compliance with the requirements in *Pt 11, Ch 2, 7 Approval of alloy steel used for intermediate shaft material*.

3.2.5 Where the scantlings of coupling bolts and straight shafting differ from the minimum required by the Rules, special consideration will be given.

3.3 Generator sets

3.3.1 Natural frequencies of the complete set are to be sufficiently removed from the firing impulse frequency at the full load speed, particularly where flexible couplings are interposed between the engine and generator.

3.3.2 Within the speed limits of 0,95N_{s} and 1,05N_{s} the vibration stresses in the transmission shafting are not to exceed the values given by the following formula:

$$\tau_c = \pm(21 - 0,014d) \text{ N/mm}^2.$$

3.3.3 Vibration stresses in the transmission shafting due to critical speeds which have to be passed through in starting and stopping, are not to exceed the values given by the following formula:

$$\tau_t = 5,5\,\tau_c.$$

3.3.4 The amplitudes of total vibratory inertia torques imposed on the generator rotors are to be limited to ±2,0Q_s in general, or to ±2,5Q_s for close-coupled revolving field alternating current generators, over the speed range from 0,95N_s to 1,05N_s. Below 0,95N_s the amplitudes are to be limited to ±6,0Q_s. Where two or more generators are driven from one engine, each generator is to be considered separately in relation to its own rated torque.

3.3.5 The rotor shaft and structure are to be designed to withstand these magnitudes of vibratory torque. Where it can be shown that they are capable of withstanding a higher vibratory torque, special consideration will be given.

3.3.6 In addition to withstanding the vibratory conditions over the speed range from 0,95N_s to 1,05N_s flexible couplings, if fitted, are to be capable of withstanding the vibratory torques and twists arising from transient criticals and short-circuit currents.

3.3.7 In the case of alternating current generators, resultant vibratory amplitudes at the rotor are not to exceed ±3,5 electrical degrees under both full load working conditions and the malfunction condition mentioned in *Pt 13, Ch 1, 2.2 Scope of calculations 2.2.3*.

3.4 Other auxiliary machinery systems

3.4.1 The relevant requirements of *Pt 13, Ch 1, 3.3 Generator sets 3.3.1*, *Pt 13, Ch 1, 3.3 Generator sets 3.3.2* and *Pt 13, Ch 1, 3.3 Generator sets 3.3.3* are also applicable to other machinery installations such as pumps or compressors.

3.5 Other machinery components

3.5.1 **Torsional vibration dampers.** The use of dampers or detuners to limit vibratory stress due to resonances which occur within the range between 0,85N_s and 1,05N_s are to be considered. If fitted, these should be of a type which makes adequate provision for dissipation of heat. Where necessary, performance monitoring may be required.

3.5.2 **Flexible couplings:**

(a) Flexible couplings included in an installation are to be capable of transmitting the mean and vibratory loads without exceeding the makers' recommended limits for angular amplitude or heat dissipation.
(b) Where calculations indicate that the limits recommended by the manufacturer may be exceeded under misfiring conditions, a suitable means is to be provided for detecting and indicating misfiring. Under these circumstances power and/or speed restriction may be required. Where machinery is non-essential, disconnection of the branch containing the coupling would be an acceptable action in the event of misfiring.

3.5.3 **Gearing:**

(a) The torsional vibration characteristics are to comply with the requirements of *Pt 13, Ch 1, 2.2 Scope of calculations*. The sum of the mean and of the vibratory torque should not exceed four-thirds of the full transmission torque, at MCR, throughout the speed range. In cases where the proposed transmission torque loading on the gear teeth is less than the maximum allowable, special consideration will be given to the acceptance of additional vibratory loading on the gears.
(b) Where calculations indicate the possibility of torque reversal, the operating speed range is to be determined on the basis of observations during sea trials.

3.6 Restricted speed and/or power ranges

3.6.1 Restricted speed and/or power ranges will be imposed to cover all speeds where the stresses exceed the limiting values, τ_c, for continuous running, including one cylinder misfiring conditions if intended to be continuously operated under such conditions. For controllable pitch propellers with the possibility of individual pitch and speed control, both full and zero pitch conditions have to be considered. Similar restrictions will be imposed, or other protective measures required to be taken, where vibratory torques or amplitudes are considered to be excessive for particular machinery items. At each end of the restricted speed range the engine is to be stable in operation.

3.6.2 The restricted speed range is to take account of the tachometer speed tolerances at the barred speeds.

3.6.3 Critical responses which give rise to speed restrictions are to be arranged sufficiently removed from the maximum revolutions per minute to ensure that, in general, at r = 0,8 the stress due to the upper flank does not exceed τ_c.

3.6.4 Provided that the stress amplitudes due to a torsional critical response at the borders of the barred speed range are less than τ_C under normal and stable operating conditions, the speed restriction derived from the following formula may be applied:

$$= \frac{16}{18-r} N_c \ to \ \frac{18-r}{16} N_c \text{ inclusive}$$

3.6.5 Where calculated vibration stresses due to criticals below $0{,}8N_S$ marginally exceed τ_C or where the critical speeds are sharply tuned, the range of revolutions restricted for continuous operation may be reduced.

3.6.6 In cases where the resonance curve of a critical speed has been derived from measurements, the range of revolutions to be avoided for continuous running may be taken as that over which the measured stresses are in excess of τ_C, having regard to tachometer accuracy.

3.6.7 Where restricted speed ranges under normal operating conditions are imposed, notice boards are to be fitted at the control stations stating that the engine is not to be run continuously between the speed limits obtained as above, and the engine tachometers are to be marked accordingly.

3.6.8 Where vibration stresses approach the limiting value, τ_t, the range of revolutions restricted for continuous operation may be extended. The notice boards are to indicate that this range must be passed through rapidly.

3.6.9 For excessive vibratory torque, stress or amplitude in other components, based on *Pt 13, Ch 1, 3.6 Restricted speed and/or power ranges 3.6.1* to *Pt 13, Ch 1, 3.6 Restricted speed and/or power ranges 3.6.4*, the limits of any speed/power restriction are to be such as to maintain acceptable levels during continuous operation.

3.6.10 Where the restrictions are imposed for the contingency of an engine malfunction or component failure, the limits are to be entered in the machinery operating manual.

3.6.11 Restricted speed ranges in one-cylinder misfiring conditions on ships with single engine propulsion are to enable safe navigation whereby sufficient propulsion power is available to maintain control of the ship.

3.6.12 There are to be no restricted speed ranges imposed above a speed ratio of $r \geq 0{,}8$ under normal operating conditions.

3.7 Tachometer accuracy

3.7.1 Where restricted speed ranges are imposed as a condition of approval, the tachometer accuracy is to be checked against the counter readings, or by equivalent means, in the presence of the Surveyors to verify that it reads correctly within ±2 per cent in way of the restricted range of revolutions.

3.8 Governor control

3.8.1 Where there is significant critical response above and close to the service speed, consideration will be given to the effect of temporary overspeed.

■ *Section 4* Measurements

4.1 General requirements

4.1.1 Where calculations indicate that the limits for torsional vibration within the range of working speeds are exceeded, measurements, using an appropriate technique, may be taken from the machinery installation for the purpose of approval of torsional vibration characteristics, or determining the need for restricted speed ranges and the confirmation of their limits.

4.1.2 Where differences between calculated and measured levels of stress, torque or angular amplitude arise, the stress limits are to be applied to the stresses measured on the completed installation.

4.1.3 The method of measurement is to be appropriate to the machinery components and the parameters which are of concern. Where shaft stresses have been estimated from angular amplitude measurements, and are found to be close to limits as defined in *Pt 13, Ch 1, 3.2 Limiting stress in propulsion shafting*, strain gauge techniques may be required. When measurements are required, detailed proposals are to be submitted.

4.2 Vibration monitoring

4.2.1 Where calculations and/or measurements have indicated the possibility of excessive vibratory stresses, torques or angular amplitudes in the event of a malfunction, vibration or performance monitoring, directly or indirectly, may be required.

■ *Section 5*
Requirements for craft which are not required to comply with the HSC Code

5.1 General requirements

5.1.1 The requirements of this Chapter do not apply to the following types of vessel having main engines not exceeding 500kW power output or auxiliary engines not exceeding 110kW output for essential services:

(a) Service craft of less than 24 m.
(b) Yachts.
(c) ACVs.

■ *Section 1* General requirements

1.1 Application

1.1.1 This Section is to be read in conjunction with the requirements of *Pt 9 General Requirements for Machinery*, *Pt 10 Prime Movers*, *Pt 11 Transmission Systems* and *Pt 12 Propulsion Devices*.

1.1.2 Unless otherwise advised, it is the responsibility of the Builder as main contractor to ensure, in co-operation with the Enginebuilders, that the information required by this Chapter is prepared and submitted.

1.1.3 The requirements of this Chapter are applicable to the following systems:

(a) Main propulsion systems formed by oil engines, turbines or electric motors, directly driven or geared to the shafting.

1.2 Power ratings

1.2.1 In this Chapter where shaft power, *P*, in kW, and revolutions per minute, *R*, are referred to, the values to be used are those defined in *Pt 9 General Requirements for Machinery*.

1.3 Basic requirements

1.3.1 For all main propulsion systems, the Builders are to ensure that axial vibration amplitudes are satisfactory throughout the speed range. Where natural frequency calculations indicate significant axial vibration responses, sufficiently wide restricted speed ranges will be imposed. Alternatively, measurements may be used to determine the speed ranges at which amplitudes are excessive for continuous running.

■ *Section 2* Details to be submitted

2.1 Particulars to be submitted

2.1.1 The results of calculations, together with recommendations for any speed restrictions found necessary.

2.1.2 The Enginebuilder's recommendation for axial vibration amplitude limits.

2.1.3 Estimate of flexibility of the thrust bearing and its supporting structure.

2.2 Scope of calculations

2.2.1 Calculations of axial vibration natural frequency are to be carried out using appropriate techniques, taking into account the effects of flexibility of the thrust bearing, for shaft systems where the propeller is:

(a) Driven directly by a reciprocating internal combustion engine.
(b) Driven via gears, or directly by an electric motor, and where the total length of shaft between propeller and thrust bearing is in excess of 60 times the intermediate shaft diameter.

2.2.2 Where an axial vibration damper is fitted, the calculations are to consider the effect of a malfunction of the damper.

■ *Section 3* Design

3.1 Symbols

3.1.1 The symbols used in this Section are as follows:

D = outside diameter of shaft, taken as an average over length l , in mm

d = internal diameter of shaft, in mm

l = length of shaft line between propeller and thrust bearing, in mm

m = mass of shaft line considered, in kg

= 0,785 $(D^2 - d^2)\, G\, l$

M = dry mass of propeller, in kg

$A = \frac{m}{M}$

$M_e = M(A + 2)$

n = number of propeller blades

k = estimated stiffness at thrust block bearing, in N/m

E = modulus of elasticity of shaft material, in N/mm^2

G = density of shaft material, in kg/mm^3

N_c = critical speed, in rev/min

3.2 Critical frequency of axial vibration

3.2.1 For those systems as defined in *Pt 13, Ch 2, 2.2 Scope of calculations 2.2.1.(b)* the propeller speed at which the critical frequency occurs may be estimated using the following formula:

$$N_c = \frac{0,98}{n}\left(\frac{ab}{a+b}\right)^{\frac{1}{2}} \text{ rev/min}$$

where

$$a = \frac{E}{Gl^2}\left(66,2 + 97,5A - 8,88A^2\right)^2 \text{ c/min}^2$$

$$b = 91,2\frac{k}{M_e} \text{ c/min}^2.$$

3.2.2 Where the results of this method indicate the possibility of an axial vibration resonance in the vicinity of the service speed, calculations using a more accurate method will be required.

3.3 Restricted speed ranges

3.3.1 The limits of any speed restriction are to be such as to maintain axial amplitudes within recommended levels during continuous operation.

3.3.2 Limits of a speed restriction, where required, may be determined from calculation or on the basis of measurement.

3.3.3 Where a speed restriction is imposed for the contingency of a damper malfunction, the speed limits are to be entered in the operating manual and regular monitoring of the axial vibration amplitude is required. Details of proposals for monitoring are to be submitted.

■ *Section 4* Measurements

4.1 General requirements

4.1.1 Where calculations indicate the possibility of excessive axial vibration amplitudes within the range of working speeds under normal or malfunction conditions, measurements are required to be taken from the shafting system for the purpose of determining the need for restricted speed ranges.

4.2 Vibration monitoring

4.2.1 Where a vibration monitoring system is to be specified, details of proposals are to be submitted.

■ *Section 5* Requirements for craft which are not required to comply with the HSC Code

5.1 General requirements

5.1.1 The requirements of this Chapter do not apply to the following types of vessel having main engines not exceeding 500kW power output or auxiliary engines not exceeding 110kW output for essential services:

(a) Service craft of less than 24 m.

(b) Yachts.

(c) ACVs.

Section 1 General requirements

1.1 Application

1.1.1 This Section is to be read in conjunction with the requirements of *Pt 9 General Requirements for Machinery*, *Pt 10 Prime Movers*, *Pt 11 Transmission Systems* and *Pt 12 Propulsion Devices*.

1.1.2 Unless otherwise advised, it is the responsibility of the Builder as main contractor to ensure, in co-operation with the Enginebuilders, that the information required by this Chapter is prepared and submitted.

1.1.3 The requirements of this Chapter are applicable to the following systems:

- Main propulsion systems formed by oil engines, turbines or electric motors, directly driven or geared to the shafting.

1.2 Power ratings

1.2.1 In this Chapter where shaft power, *P*, in kW, and revolutions per minute, *R*, are referred to, the values to be used are those defined in *Pt 9 General Requirements for Machinery*.

1.3 Basic requirements

1.3.1 For all main propulsion shafting systems, the Builders are to ensure that lateral vibration characteristics are satisfactory throughout the speed range.

Section 2 Details to be submitted

2.1 Particulars to be submitted

2.1.1 Calculations of the lateral vibration characteristics of shafting systems having supports outboard of the hull or incorporating cardan shafts are to be submitted.

2.2 Calculations

2.2.1 The calculations in *Pt 13, Ch 3, 2.1 Particulars to be submitted 2.1.1*, taking account of bearing, oil-film (where applicable) and structural dynamic stiffnesses, are to investigate the excitation frequencies which may result in significant amplitudes within the speed range, and are to indicate relative deflections and bending moments throughout the shafting system.

Section 3
Measurements

3.1 General requirements

3.1.1 Where calculations indicate the possibility of significant lateral vibration responses within the range of working speeds, measurements using an appropriate recognised technique may be required to be taken from the shafting system for the purpose of determining that hazardous whirling or excessive vibration does not occur.

3.1.2 The method of measurement is to be appropriate to the machinery arrangement and the modes of vibration which are of concern. When measurements are required, detailed proposals are to be submitted in advance.

Section 4
Requirements for craft which are not required to comply with the HSC Code

4.1 General requirements

4.1.1 The requirements of this Chapter do not apply to the following types of vessel having main engines not exceeding 500 kW power output unless the spacing of bearings on the propulsion shafting exceeds 30 diameters or cardan shafts are used in the propulsion shafting system:

(a) Service craft of less than 24 m.
(b) Yachts.
(c) ACVs.

■ *Section 1* Shaft alignment

1.1 General

1.1.1 The Builder is to carry out shaft alignment calculations for all installations and to prepare alignment procedures detailing the proposed alignment method and the alignment checks.

1.2 Particulars to be submitted for approval - Shaft alignment calculations

1.2.1 Shaft alignment calculations are to be submitted to LR for approval for the following shafting systems:

(a) All geared installations where the screwshaft has a diameter of 300 mm or greater in way of the aftmost bearing.
(b) All geared installations with multiple input/single output, regardless of shaft diameter.
(c) All direct drive installations which incorporate three or fewer bearings supporting the intermediate and screwshaft aft of the prime mover.
(d) Where prime movers in a direct drive installation or shaftline bearings are installed on resilient mountings.

1.2.2 The shaft alignment calculations are to take into account the:

(a) thermal displacements of the bearings between cold static and hot dynamic machinery conditions;
(b) buoyancy effect of the propeller immersion due to the craft's operating draughts;
(c) effect of predicted hull deformations over the range of the craft's operating draughts, where known;
(d) gear forces, where appropriate;
(e) combinations of engine inputs for multiple input and single output installations;
(f) propeller offset thrust effects, where applicable;
(g) bearing loading in the horizontal plane, where appropriate; and
(h) bearing weardown, where applicable, and its effect on the bearing loads.

1.2.3 The shaft alignment calculations are to state the:

(a) expected bearing loads at light and normal ballast, fully loaded and any other draughts deemed to be part of the craft's operating profile, for the machinery in cold and hot, static and dynamic conditions;
(b) bearing influence coefficients and the deflection, slope, bending moment and shear force along the shaftline;
(c) details of propeller offset thrust effects, where employed in calculation;
(d) details of proposed slope-bore of the aftermost sterntube bearing, where applicable;
(e) manufacturer's specified limits for bending moment and shear force at the shaft couplings of the gearbox/prime movers;
(f) estimated bearing weardown rates for water or grease-lubricated sterntube bearings;
(g) origin of findings where the effect of hull deformation has been considered, *viz*. whether finite element calculations or measured results from sister or similar craft have been used;
(h) anticipated thermal rise of prime movers and gearing units between cold static and hot running conditions; and
(i) manufacturer's allowable bearing loads.

1.3 Particulars to be submitted for review - Shaft alignment procedure

1.3.1 A shaft alignment procedure is to be submitted for all main propulsion installations detailing, as a minimum, the:

(a) expected bearing loads at light and normal ballast, fully loaded and any other draughts deemed to be part of the craft's operating profile, for the machinery in cold and hot, static and dynamic conditions;
(b) maximum permissible loads for the proposed bearing designs;

(c) design bearing offsets from the straight line;
(d) design gaps and sags;
(e) location and loads for the temporary shaft supports;
(f) expected relative slope of the shaft and the bearing in the aftermost sterntube bearing;
(g) details of slope-bore of the aftermost sterntube bearing, where applied;
(h) expected shear forces and bending moments at the forward end flange of the shafting system connecting to the gear output shaft or, for direct-drive installations, to the prime mover output flange;
(i) proposed bearing load measurement technique and its estimated accuracy;
(j) jack correction factors for each bearing where the bearing load is measured using a specified jacking technique;
(k) proposed shaft alignment acceptance criteria, including the tolerances; and
(l) flexible coupling alignment criteria.

1.4 Design and installation criteria

1.4.1 For main propulsion installations, the shafting is to be aligned to give, in all conditions of craft loading and machinery operation, bearing load distribution satisfying the requirements of *Pt 13, Ch 4, 1.4 Design and installation criteria 1.4.2*.

1.4.2 Design and installation of the shafting is to satisfy the following criteria:

(a) The Builder is to position the bearings and construct the bearing seatings to minimise the effects of hull deflections under any of the craft's operating conditions.
(b) Relative slope between the propeller shaft and the aftermost sterntube bearing is, in general, not to exceed 3×10^{-4} rad.
(c) Sterntube bearing loads are to satisfy the requirements of *Pt 11, Ch 2, 4.16 Sternbushes and sterntube arrangements 4.16.2*.
(d) Intermediate shaft bearings' loads are not to exceed 80 per cent of the bearing manufacturer's allowable maximum load, for plain journal bearings, based on the bearing projected area.
(e) Main gear wheel bearing loads are to be within the gearbox manufacturer's specified limits.
(f) Resulting shear forces and bending moments are to meet the equipment manufacturer's specified coupling conditions throughout the shafting system.
(g) The manufacturer's radial, axial and angular alignment limits for the flexible couplings are to be maintained.

1.5 Measurements

1.5.1 Where calculations indicate that the system is sensitive to changes in alignment under different service conditions, the optimised shaft alignment is to be verified by measurements during sea trials using an approved strain gauge technique.

1.6 Flexible couplings

1.6.1 Where the shafting system incorporates flexible couplings, the effects of such couplings on the various modes of vibration are to be considered, *see Pt 13, Ch 4, 2 Requirements for craft which are not required to comply with the HSC Code*.

■ *Section 2*
Requirements for craft which are not required to comply with the HSC Code

2.1 General requirements

2.1.1 The requirements of *Pt 13, Ch 4, 1 Shaft alignment* do not apply to the following types of craft where the main engine does not exceed 500kW power output:

(a) Service craft of less than 24 m.
(b) Yachts.
(c) ACVs.

2.1.2 The engines, shafting, sterntubes and propeller brackets are to be carefully fitted and well secured to the hull of the craft so that satisfactory alignment of the shafting will be maintained in service.

2.1.3 The alignment of the sterntube and propeller brackets is to be demonstrated before launching and the shafting and engine alignment verified when afloat.

Contents

■ *Section 1*
General requirements

1.1 Application

1.1.1 This Chapter is to be read in conjunction with the General Requirements for Machinery in *Pt 9 General Requirements for Machinery*.

1.1.2 The requirements given in *Pt 5, Ch 19 Steering Systems* of the *Rules and Regulations for the Classification of Ships, July 2021* are to be applied to vessels required to comply with SOLAS.

1.1.3 The requirements of this Chapter apply to the design and construction of steering systems.

1.1.4 A steering system includes:

- all steering devices;
- all mechanical, electrical, and hydraulic linkages;
- all power devices, including manual devices;
- all controls and all actuating systems.

1.1.5 Steering may be achieved by means of:

- air or water rudders;
- foils, flaps, steerable propellers or jets;
- yaw control ports or transverse thrusters;
- differential propulsive thrust,
- variable geometry of the craft or its lift system components; or
- by a combination of these devices.

1.2 Provision of steering gear

1.2.1 Craft are to be provided with a means for steering which is to be of adequate strength and suitable design to enable the craft's heading and direction of travel to be effectively controlled at all designed operating conditions.

1.2.2 Craft are to be provided with a main steering system and an independent auxiliary steering unit. The main and the auxiliary steering units are to be so arranged that the failure of one of them will not render the other one inoperative or unable to bring the craft to a safe situation.

1.2.3 An auxiliary steering system is not a requirement provided the craft is fitted with two independent and identical steering systems, one of which is capable of steering the craft when the second system becomes inoperative.

1.3 Definitions

1.3.1 **Main steering system** means the machinery, the actuator(s), the power units, if any, ancillary equipment and the means of applying the steering torque, if applicable, necessary for the purpose of steering the craft under design conditions.

1.3.2 **Auxiliary steering system** means the equipment other than any part of the main steering unit necessary to steer the craft in the event of failure of the main steering system.

1.3.3 **Steering power system** means:

(a) In the case of electric steering system, an electric motor and its associated electrical parts.
(b) In the case of electrohydraulic steering system, an electric motor and its associated electrical parts and connected pump.
(c) In the case of other hydraulic steering system units, a driving engine and connected pump.

1.3.4 **Steering control system** means the equipment by which orders are transmitted from the control station to the steering power units. Steering control systems comprise transmitters, receivers, hydraulic control pumps and their associated motors, motor controllers, piping and cables.

1.3.5 **Maximum working pressure** means the expected pressure in the system when the steering unit is operated under the most onerous design condition.

1.3.6 **Power actuating system** means the hydraulic equipment provided for supplying power to turn the rudder stock, comprising a steering power system or systems, together with the associated pipes and fittings, and a rudder actuator. The power actuating systems may share common mechanical components, i.e. tiller quadrant and rudder stock, or components serving the same purpose.

■ *Section 2* Particulars to be submitted

2.1 Submission of information

2.1.1 At least three copies of the plans and information as detailed in *Pt 14, Ch 1, 2.2 Plans* and *Pt 14, Ch 1, 2.3 Calculations and information* are to be submitted.

2.2 Plans

2.2.1 Detailed plans of all load bearing, and torque transmitting components and hydraulic pressure retaining parts of the steering system together with proposed rated torque, all relief valve settings, and scantlings.

2.2.2 Schematic of the hydraulic systems, together with pipe material, relief valve and working pressures.

2.2.3 Details of control engineering aspects in accordance with *Pt 16, Ch 1 Control Engineering Systems*.

2.3 Calculations and information

2.3.1 The manoeuvring characteristics for which the craft has been designed.

2.3.2 Material specifications.

■ *Section 3* Materials

3.1 General

3.1.1 All components are to be in accordance with the *Rules for the Manufacture, Testing and Certification of Materials, July 2021* (hereinafter referred to as the Rules for Materials).

3.1.2 All steering unit components transmitting mechanical forces are to be of steel or other approved ductile material. In general, such material is to have an elongation of not less than 12 per cent nor a tensile strength in excess of 650 N/mm^2. Special

consideration will be given to the acceptance of grey cast iron for low pressure valve bodies and mechanical parts with low stress levels.

3.1.3 Consideration will be given to the acceptance of non-ferrous materials as applicable.

■ *Section 4*
Design and performance

4.1 General

4.1.1 Power-operated steering units are to be provided with positive arrangements, such as limit switches, for stopping the unit before the mechanical stops are reached. These arrangements are to be synchronized with the unit itself and not with the steering unit control mechanism.

4.1.2 The steering unit is to be secured to the seating by fitted bolts, and suitable chocking arrangements are to be provided. The seating is to be of substantial construction.

4.1.3 All welded joints within the pressure boundary of an actuator or connecting parts transmitting mechanical loads are to be of full penetration type or of equivalent strength.

4.1.4 Steering devices involving variable geometry of the craft or its lift system components are to be so constructed that any failure of the drive linkage or actuating system will not significantly hazard the craft.

4.2 Actuating systems

4.2.1 Actuators are to be designed in accordance with the relevant requirements of *Pt 15 Piping Systems and Pressure Plant* for Class I pressure vessels (notwithstanding any exemptions for hydraulic cylinders).

4.2.2 Accumulators, if fitted, are to comply with the relevant requirements of *Pt 15 Piping Systems and Pressure Plant*.

4.2.3 The design pressure for calculations to determine the scantlings of piping and other steering components subjected to internal hydraulic pressure shall be at least 1,25 times the maximum working pressure to be expected under the operational conditions specified taking into account any pressure which may exist in the low pressure side of the system. Fatigue criteria may be applied for the design of piping and components, taking into account pulsating pressures due to dynamic loads.

4.2.4 The permissible primary general membrane stress is not to exceed the lower of the following values:

$$\frac{\sigma_{\rm B}}{A} \; or \; \frac{\sigma_{\rm y}}{B}$$

where

σ_B = specified minimum tensile strength of material at ambient temperature

σ_y = specified minimum yield stress or 0,2 per cent proof stress of the material, at ambient temperature

A and *B* are given by the following Table:

	Wrought steel	Cast steel	Nodular cast iron
A	3,5	4	5
B	1,7	2	3

4.2.5 Oil seals between non-moving parts, forming part of the external pressure boundary, should be of the metal upon metal type or of an equivalent type.

4.2.6 Hydraulic power operated steering units are to be provided with the following :

(a) Arrangements to maintain the cleanliness of the hydraulic fluid taking into consideration the type and design of the hydraulic system;

(b) A fixed storage tank having sufficient capacity to recharge at least one power actuating system including the reservoir. The storage tank is to be provided with a contents gauge and be permanently connected by piping in such a manner that the hydraulic systems can be readily recharged from a position within the steering unit compartment, if applicable.

4.3 Rudder systems

4.3.1 For the requirements of rudder and rudder stock, see *Pt 3, Ch 3 Control Systems*.

4.3.2 Tillers and quadrants are to comply with the requirements of *Table 1.4.1 Connection of tiller to stock*.

4.3.3 On double rudder installations, where the two tillers are connected by mechanical means (tie-bar), the strength and stability of the tie-bar is to be assessed using the maximum steering torque applied to the stock.

4.3.4 Where higher tensile steel bolts are used on bolted tillers and quadrants, the yield and ultimate tensile stresses of the bolt material are to be stated on plans submitted for approval, together with full details of the methods to be adopted to obtain the required setting-up stress. Where proprietary nuts or systems are used, the manufacturer's instructions for assembly are to be adhered to.

4.3.5 All steering components transmitting mechanical forces to the rudder stock, which are not protected against overload by structural rudder stops or mechanical buffers, are to have a strength at least equivalent to that of the rudder stock in way of the tiller.

Table 1.4.1 Connection of tiller to stock

(1) Dry fit - tiller to stock for M_T (*see* Notes)	(a) For keyed connection, factor of safety against slippage = 1,1 (b) For keyless connection, factor of safety against slippage = 2,2 (c) Coefficient of friction = 0,17 (d) Grip stress not to be less than 20 N/mm^2
(2) Hydraulic fit - tiller to stock for M_T (*see* Notes)	(a) For keyed connection, factor of safety against slippage = 1,1 (b) For keyless connection, factor of safety against slippage = 2,2 (c) Coefficient of friction = 0,12 (d) Grip stress not to be less than 20 N/mm^2
(3) Bolted tiller and quadrant (*see* Symbols and Notes)	Shim to be fitted between two halves before machining to take rudder stock, then removed prior to fitting Minimum thickness of shim: For 4 connecting bolts: $t_s = 0{,}0014 d_{SU}$ mm For 6 connecting bolts: $t_s = 0{,}0012 d_{SU}$ mm Key to be fitted Diameter of bolts, $\delta_T = \frac{0,60 d_{SU}}{\sqrt{n_T}}$ *mm* Distance from centre of stock to centre of bolts should generally be equal to $d_{SU}\left(1,0 + \frac{0,30}{\sqrt{n_T}}\right)$ *mm* Thickness of flange on each half of the bolted tiller $\frac{0,66 d_{SU}}{\sqrt{n_T}}$ *mm*

(4) Key (*see* Symbols and Notes)	Effective sectional area in shear ≥ $0{,}25d_{SU}^{2}$ mm^2 Key thickness ≥ $0{,}17d_{SU}$ mm Keyway is to extend over full depth of tiller and is to have a rounded end. Corners are to be provided with suitable radii to avoid high stress at the keyway root.
(5) Section modulus - tiller arm (at any point within its length about vertical axis) (*see* Symbols and Notes)	To be not less than the greater of: (a) $Z_{TA} = \dfrac{0{,}15d_{SU}^{3}(b_T - b_s)}{1000b_T}$ cm^3 (b) $Z_{TA} = \dfrac{0{,}06d_{SU}^{3}(b_T - 0{,}9d_{SU})}{1000b_T}$ cm^3 If more than one arm is fitted, combined modulus is not to be less than the greater of (a) or (b). For solid tillers, the breadth to depth ratio is not to exceed 2.
(6) Boss (*see* Symbols and Notes)	Depth of boss ≥ d_{SU} Thickness of boss in way of tiller ≥ $0{,}4d_{SU}$
Symbols	
b_s = distance between the section of the tiller arm under consideration and the centre of the rudder stock, in mm	Z_{TA} = section modulus of tiller arm, in cm^3
NOTE: b_T and b_s are to be measured with zero rudder angle	d_{SU} = *see Pt 3, Ch 3 Control Systems*
b_T = distance from the point of application of the load on the tiller to the rudder stock, in mm	δ_T = diameter of bolts securing bolted tillers and quadrants, in mm
n_T = number of bolts in coupling, but generally not to be taken greater than six	σ_o = minimum yield stress or 0,5 per cent proof stress of the tiller bolt material, in N/mm^2
t_s = thickness of shim for machining bolted tillers and quadrants, in mm	
Note 1. If d_{SU} > 400 mm, higher tensile steel bolts are to be used for bolted tillers. A predetermined setting-up load equivalent to a stress of approximately 0,7 σ_o should be applied to each bolt assembly. A lower stress may be accepted provided that two keys, complying with item (4) are fitted. Note 2. Where M_T, the maximum turning moment applied to the stock, is to be taken as the greater of the following: (a) $11{,}1d_{SU}^{3}$ Nmm, where d_{SU} is to be determined from *Table 3.2.6 Rudder stock diameter* in Pt 3, Ch 3 with σ_o taken as 235 N/mm^2 and N= 0. (b) The torque generated by the steering gear at the maximum working pressure, *see Pt 14, Ch 1, 1.3 Definitions 1.3.5*.	

4.3.6 In bow rudders having a vertical locking pin operated from the deck above, positive means are to be provided to ensure that the pin can be lowered only when the rudder is exactly central. In addition, an indicator is to be fitted at the deck to show when the rudder is exactly central.

4.4 Performance

4.4.1 The main steering system is to be:

(a) Of adequate strength and capable of steering the craft at all speeds and conditions for which the craft is designed and this shall be demonstrated during trials,

(b) operated by power where necessary to meet the requirements of (a) and in any case when the Rules require a rudder stock over 120 mm diameter in way of the tiller; and

(c) so designed that it will not be damaged at maximum astern speed.

4.4.2 The auxiliary steering system is to be:

(a) Of adequate strength and capable of steering the craft at navigable speed and of being brought speedily into action in an emergency;
(b) Operated by power where necessary to meet the requirements of (a) and in any case when the Rules, require a rudder stock over 230mm diameter in way of the tiller.
(c) Where manual operated steering units are proposed, these are acceptable when the operation does not require an effort exceeding 160N under normal conditions.

4.4.3 Main and auxiliary steering power units are to be:

(a) Arranged to re-start automatically when power is restored after power failure;
(b) Capable of being brought into operation from a position at the control station. In the event of a power failure to any one of the steering power units, an audible and visual alarm is to be given on the control station;
(c) Arranged so that transfer between units can be readily effected.

4.4.4 For high speed craft, in the event of total power failure, either:

(a) emergency power for steering systems/drives is to be restored automatically within five seconds. To achieve this an interim fast acting system may be required to come into operation until such time as auxiliary/emergency power source comes on line. (Note: starting arrangements are to comply with the requirements relating to starting arrangements of emergency generators); or
(b) means are to be provided to bring the craft to a safe condition.

4.4.5 Where the steering unit is so interconnected that more than one power system, or control system, can be simultaneously operated, the design is to be such that hydraulic locking caused by a single failure cannot occur.

4.4.6 Steering systems, other than of the hydraulic type, will be accepted provided the standards are considered equivalent to the requirements of this Section.

■ *Section 5*
Piping systems

5.1 Components

5.1.1 Piping, joints, valves, flanges and other fittings are to comply within the requirements of *Pt 15, Ch 1 Piping Design Requirements* for Class 1 piping system components. The design pressure is to be in accordance with *Pt 14, Ch 1, 4.2 Actuating systems 4.2.3*.

5.2 Valve and relief valve arrangements

5.2.1 For vessels with non-duplicated actuators, isolating valves are to be fitted at the connection of pipes to the actuator, and are to be directly fitted on the actuator.

5.2.2 Arrangements for bleeding air from the hydraulic system are to be provided, where necessary.

5.2.3 Relief valves are to be fitted to any part of the hydraulic system which can be isolated and in which pressure can be generated from the power source or from external forces. The settings of the relief valves is not to exceed the design pressure. The valves are to be of adequate size and so arranged as to avoid an undue rise in pressure above the design pressure.

5.2.4 Relief valves for protecting any part of the hydraulic system which can be isolated, as required by *Pt 14, Ch 1, 5.2 Valve and relief valve arrangements 5.2.3* are to comply with the following:

(a) The setting pressure is not to be less than 1,25 times the maximum working pressure.
(b) The minimum discharge capacity of the relief valve(s) is not to be less than 110 per cent of the total capacity of the pumps which can deliver through it (them).

Under such conditions the rise in pressure is not to exceed 10 per cent of the setting pressure. In this regard, due consideration is to be given to extreme foreseen ambient conditions in respect of oil viscosity.

5.3 Flexible hoses

5.3.1 Flexible hoses are to be of approved type, *see Pt 15, Ch 1, 13 Flexible hoses*.

■ *Section 6*
Control, monitoring and electrical equipment

6.1 Control

6.1.1 In addition to this section, the control and electrical installation of the steering control system is to comply with *Pt 16 Control and Electrical Engineering*.

6.1.2 All steering systems are to be operated from the craft's control station.

6.1.3 If steering systems can also be operated from other positions, then two-way communication is to be arranged between the control station and these other positions.

6.1.4 Steering control is to be provided:

(a) For the main steering unit, both at the control station and in the steering unit compartment, where applicable;
(b) Where the main steering unit is arranged by two independent control systems, both operable from the control station. This does not require duplication of the steering wheel or steering lever. Where the control system consists of a hydraulic telemotor, a second independent system need not be fitted.
(c) For the auxiliary steering unit, in the steering unit compartment and, if power operated, it is also to be operable from the control station and is to be independent of the control system for the main steering system.

6.1.5 Electrical control systems are to be independent and separated as far as is practicable throughout their length.

6.1.6 Any main and auxiliary steering unit control system operable from the control station is to comply with the following:

(a) Means are to be provided in the steering unit compartment, if applicable, for disconnecting any control system operable at the control station from the steering unit it serves;
(b) The system is to be capable of being brought into operation from a position on the control station.

6.1.7 Appropriate operating instructions with a block diagram showing the change-over procedures for steering unit control systems and steering unit actuating systems are to be permanently displayed at the control station and in the steering unit compartment, if applicable.

6.1.8 Arrangements for failure detection are to be provided with self-monitoring capabilities. In the event of failure being detected, an audible and individual visual alarm is to be initiated on the navigating bridge. *See Pt 14, Ch 1, 6.2 Monitoring and alarms*. Where the system failure alarms for hydraulic lock, *see Table 1.6.1 Alarms*, are provided, appropriate instructions are to be placed on the control station to shut down the system at fault.

6.1.9 In the event of detecting a control system failure, which is likely to cause uncontrolled rudder movements, *see Table 1.6.1 Alarms*, the rudder is to retain its position at the time of failure without manual intervention. Alternatively, consideration will be given to the rudder moving to and retaining a position which is necessary for safe navigation of the craft or to return to the mid-ship position where technical justification is submitted and is found to be satisfactory.

6.2 Monitoring and alarms

6.2.1 Alarms and monitoring requirements are indicated in *Pt 14, Ch 1, 6.2 Monitoring and alarms 6.2.2*, *Pt 14, Ch 1, 6.2 Monitoring and alarms 6.2.3* and *Table 1.6.1 Alarms*.

6.2.2 The angular position of the steering mechanism is to:

(a) Where the main steering unit is power operated, be indicated at the control station, and other positions as applicable. The angular indication is to be independent of the steering unit control system; and is to indicate any abnormal responses or malfunctions. The logic of such feedback and indications are to be consistent with the other alarms and indications so that in an emergency operators are unlikely to be confused.
(b) Be recognisable in the steering unit compartment, if applicable.

6.2.3 The alarms described in *Table 1.6.1 Alarms* re to be indicated on the navigating bridge and the additional locations described and are to be in accordance with the alarm system specified by *Pt 16, Ch 1, 2.3 Alarm systems*.

6.2.4 Steering control systems are to be monitored and an audible and visual alarm is to be initiated on the navigation bridge in the event of:

- failure of the control system, including command and fee back circuits; or
- unacceptable deviation between the rudder order and actual rudder position and/or unacceptable delay in response to changes in the rudder order.

Table 1.6.1 Alarms

Item	Alarm	Note
Angular position of the Steering Mechanism	-	Indication, *see Pt 14, Ch 1, 6.1 Control 6.1.7*
	Failure	*See Pt 14, Ch 1, 6.2 Monitoring and alarms 6.2.4*
Earthing on AC and DC circuits	Fault	If galvanically isolated from the ship's network
Data communication	Error	Where the data deviates from expected value, sequence or timing
Steering power units, power	Failure	-
Steering motors	Overload Single phase	For alarm and running indication locations, *see Pt 14, Ch 1, 6.3 Electrical equipment 6.3.3* and *Pt 14, Ch 1, 6.3 Electrical equipment 6.3.4*
Control system	Failure	*See Pt 14, Ch 1, 6.2 Monitoring and alarms 6.2.4*
Control system power	Failure	-
Steering gear hydraulic oil tank level	Low	Each reservoir to be monitored. For Alarm locations, *see Pt 14, Ch 1, 6.3 Electrical equipment 6.3.5*
Auto pilot	Failure	Running indication
Hydraulic oil temperature	High	Where oil cooler is fitted
Hydraulic lock	Fault	Where more than one system (either power or control) can be operated simultaneously each system is to be monitored *see* Note
Hydraulic oil filter differential pressure	High	When oil filters are fitted

Note This alarm is to identify the system at fault and to be activated when (for example):

- position of the variable displacement pump control system does not correspond with given order; or
- incorrect position of 3-way full flow valve or similar in constant delivery pump system is detected.

6.3 Electrical equipment

6.3.1 Short circuit protection, and overload alarm and, in the case of polyphase circuits, an alarm to indicate failure of any one of the phases is to be provided for each main and auxiliary motor circuit. Protective devices are to operate at not less than twice the full load current of the motor or circuit protected and are to allow excess current to pass during the normal accelerating period of the motors.

6.3.2 Where steering motor circuits are supplied by converters, consideration will be given to arrangements that provide an equivalent level of safety, reliability, availability and indication to those specified in *Pt 14, Ch 1, 6.3 Electrical equipment 6.3.1*, provided that technical justification is submitted.

6.3.3 The alarms required by *Pt 14, Ch 1, 6.3 Electrical equipment 6.3.1* are to be provided on the bridge and in the main machinery space or control room from which the main machinery is normally controlled.

6.3.4 Indicators for running indication of each main and auxiliary motor are to be installed on the control station and at a suitable main machinery control position.

6.3.5 A low-level alarm is to be provided for each steering system hydraulic fluid reservoir to give the earliest practicable indication of hydraulic fluid leakage. Alarms are to be given on the navigation bridge and in the machinery space where they can be readily observed.

6.3.6 Two exclusive circuits are to be provided for each electric or electrohydraulic steering unit arrangement consisting of one or more electric motors.

6.3.7 Each of these circuits is to be fed from the main switchboard. One of these circuits may pass through the emergency switchboard.

6.3.8 One of these circuits may be connected to the motor of an associated auxiliary electric or electrohydraulic power unit.

6.3.9 Each of these circuits is to have adequate capacity to supply all the motors which can be connected to it and which can operate simultaneously.

6.3.10 These circuits are to be separated throughout their length as widely as is practicable.

6.3.11 Each main and auxiliary electric control system which is to be operated from the control station is to comply with the following:

(a) It is to be served with electric power by a separate circuit supplied from the associated steering unit power circuit, from a point within the steering unit compartment, or directly from the same section of switchboard busbars, main or emergency, to which the associated steering unit power circuit is connected.
(b) Each separate circuit is to be provided with short circuit protection only.

■ *Section 7*
Requirements for craft which are not required to comply with the HSC Code

7.1 Introduction

7.1.1 The requirements of *Pt 14, Ch 1, 1 General requirements* of this Chapter apply, except where modified by this Section.

7.2 Design and performance

7.2.1 In craft over 50 m in length, the main steering system is to be power operated.

7.2.2 Service craft of length 50 m or less, or sailing yachts of length 50 m or less, may have manual steering. Where wheel steering is fitted, an alternative means of steering (which may be a hand tiller) is to be readily available, and the performance of both systems is to be in accordance with *Pt 14, Ch 1, 7.2 Design and performance 7.2.8*.

7.2.3 The main steering gear is to be capable of steering the craft at the maximum ahead speed and turning the rudder from hardover to hardover in 30 seconds.

7.2.4 Where wire rope steering leads are fitted, they are to be of suitable construction. Wire rope is to be stainless steel or suitably protected against corrosion and the strength of the rope is to be as follows:

$$\text{Breaking load} = \frac{{d_{su}}^3}{100R}\ \text{kN}$$

where d_{su} is the basic stock diameter at quadrant or tiller given by *Table 3.2.6 Rudder stock diameter* in mm.

R = radius of quadrant, or length of tiller arm, in mm

7.2.5 Steering leads are to be as direct as possible, and sharp bends are to be avoided. Sheaves are to be of adequate diameter and designed to prevent the steering leads from jumping or jamming.

7.2.6 Means are to be provided for adjusting the tension in the steering leads.

7.2.7 Where considered necessary, an efficient locking or brake arrangement is to be fitted to keep the rudder steady when a change from one type of steering to the other is required.

7.2.8 Where manually operated steering is permitted, *see Pt 14, Ch 1, 7.2 Design and performance 7.2.2*, the effort required to operate the tiller or steering wheel is to be not more than 160N under normal conditions.

7.3 Control and monitoring

7.3.1 The alarms and safeguards for yachts and service craft less than 24 m are to be adequate for the type of steering system employed, *see Table 1.7.1 Alarms*.

Table 1.7.1 Alarms

Item	Alarm	Note
Angular position of the Steering Mechanism	-	Indication
Steering power units, power	Failure	-
Steering motors	Overload, single phase	Also running indication on bridge
Control system power	Failure	-
Steering gear hydraulic oil level	Low	-
Auto pilot	Failure	Running indication
Hydraulic oil temperature	High	Where oil cooler is fitted

7.3.2 The requirements of *Pt 14, Ch 1, 6.3 Electrical equipment 6.3.6* do not apply to service craft less than 24 m.

7.4 Electrical equipment

7.4.1 Consideration will be given to the electrical control equipment of simple steering systems on service craft less than 24 m or yachts, *see Pt 16, Ch 2 Electrical Engineering*.

Contents

■ *Section 1* Application

1.1 General

1.1.1 The requirements of this Chapter apply to the design and construction of piping systems including pipe fittings forming part of such systems.

1.1.2 Requirements for small craft of less than 24 m not required to comply with the HSC Code are given in *Pt 15, Ch 1, 15 Requirements for small craft which are not required to comply with the HSC Code*.

1.2 Definitions

1.2.1 **Piping system** includes pipes and fittings such as expansion joints, valves, pipe joints, support arrangements, flexible tube lengths, etc. and components in direct connection with the piping such as pumps, heat exchangers, air receivers, independent tanks, etc.

■ *Section 2* Details to be submitted

2.1 Plans and information

2.1.1 At least three copies of the following plans and information are to be submitted.

2.1.2 Venting, sounding and drainage arrangements for all watertight compartments.

2.1.3 The following diagrammatic plans including details of the material and pipe dimensions/thickness:

- Bilge and ballast systems including the capacities of the pumps on bilge service.
- Fuel oil systems.
- Tank overflow arrangements
- Lubricating oil systems.
- Flammable liquids used for control and heating systems.
- Power transmission systems for services essential for safety or for the operation of the craft at sea.
- Cooling water systems for main and auxiliary services.
- Compressed air system for main and auxiliary services.
- Steam systems with a design pressure above 7 bar.

2.1.4 Arrangement of fuel oil storage tanks with a capacity of over 0,5 m^3 where these do not form part of the structure of the craft.

2.1.5 Where it is intended to use plastic pipes for Class I, Class II and any Class III systems for which there are requirements in these Rules, details of the following:

(a) Properties of the materials.
(b) Operating conditions.
(c) Intended service and location.
(d) Pipes, fittings and joints.

2.1.6 Design details of the following components:

(a) Flexible hoses.
(b) Sounding devices.
(c) Resiliently seated valves.
(d) Expansion joints.
(e) Components of an unusual or novel nature.

2.1.7 For craft having two or more main engines and multi-hull craft:

- The number of main engines required by the craft to navigate safely.

2.1.8 The requirements for plans and information for the fire-fighting systems are given in *Pt 17, Ch 1, 1.2 Submission of plans and information 1.2.3*.

■ *Section 3* Classes of piping systems and components

3.1 General

3.1.1 Pressure piping systems are divided into three classes for the purpose of assigning appropriate testing requirements, types of joints to be adopted, heat treatment and weld procedure.

3.1.2 Dependent on the service for which they are intended, Class II and III pipes are not to be used for design pressure or temperature conditions in excess of those shown in *Table 1.3.1 Maximum pressure and temperature conditions for Class II and III piping systems*. Where either the maximum design pressure or temperature exceeds that applicable to Class II pipes, Class I pipes are to be used. To illustrate this, *see Figure 1.3.1 Classes of piping system*.

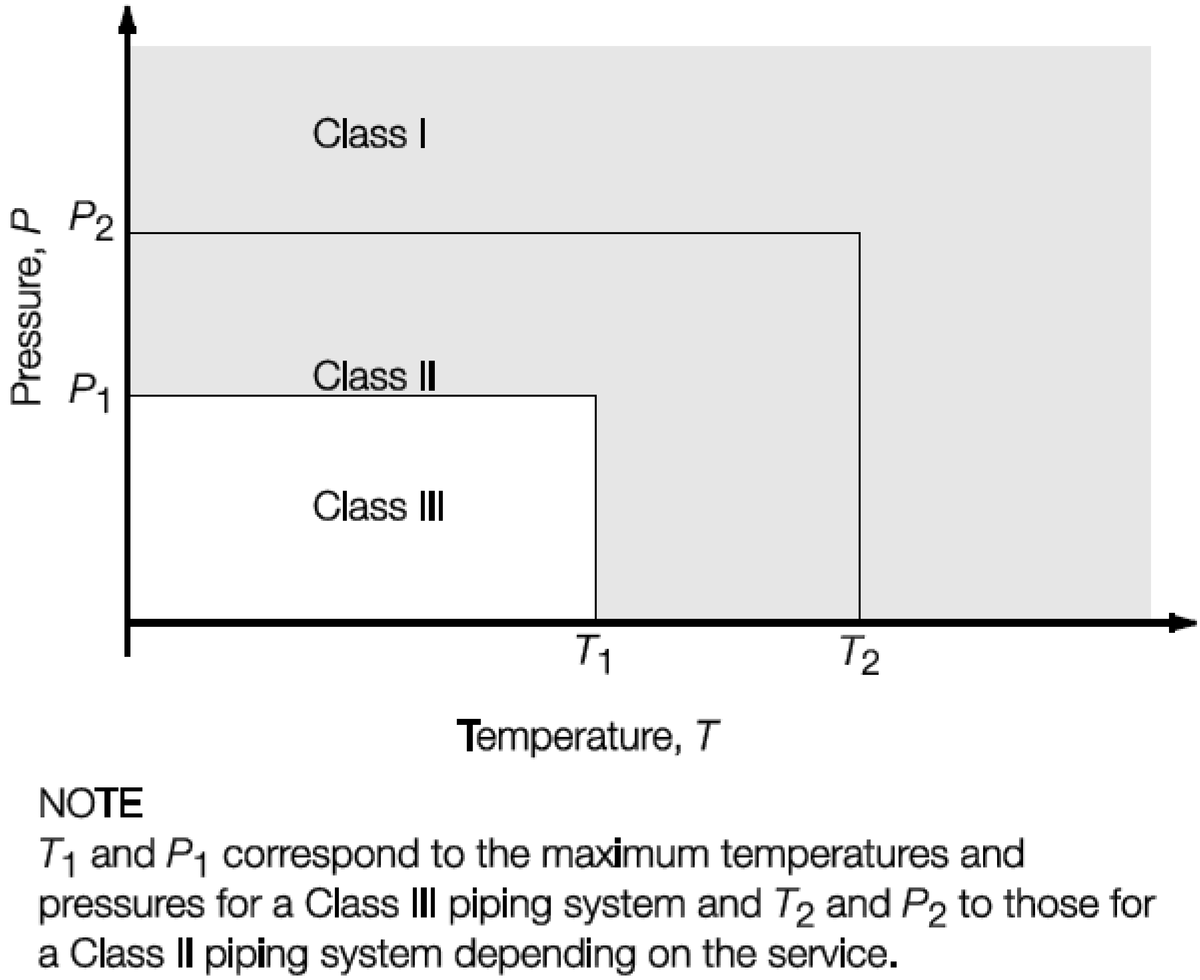


Figure 1.3.1 Classes of piping system

Table 1.3.1 Maximum pressure and temperature conditions for Class II and III piping systems

Piping system	Class II		Class III	
	P_2	T_2	P_1	T_1
	bar	°C	bar	°C
Steam	16,0	300	7,0	170
Thermal oil	16,0	300	7,0	150
Flammable liquids, *see* Note 1	16,0	150	7,0	60
Other media, *see* Note 2	40,0	300	16,0	200

Note 1. Flammable liquids include: fuel oil, lubricating oil and flammable hydraulic oil.

Note 2. Including water, air, gases, non-flammable hydraulic oil.

3.1.3 In addition to the pressure piping systems in *Table 1.3.1 Maximum pressure and temperature conditions for Class II and III piping systems*, Class III pipes may also be used for open-ended piping, e.g. overflows, vents, boiler waste steam pipes, open ended drains, sounding pipes, etc.

3.1.4 Class II and III pipes are not to be used for toxic media.

3.1.5 Class I pipes are generally required for corrosive media. Class II pipes may be used for corrosive media where special safeguards for reducing the potential for leakage and limiting its consequences are provided, e.g. the use of pipe ducts, shielding, screening, etc. in such a way that a leakage will not cause a potential hazard or damage to surrounding areas. Class III pipes are not to be used for corrosive media. Materials used for piping for corrosive media are to be specially considered.

3.1.6 For piping systems or components using cast iron, *see Pt 15, Ch 1, 7 Cast iron*.

■ *Section 4*
Design symbols and definitions

4.1 Design symbols

4.1.1 The symbols used in this Chapter are defined as follows:

a = percentage negative manufacturing tolerance on thickness

c = corrosion allowance, in mm

d = inside diameter of pipe, in mm, *see Pt 15, Ch 1, 4.1 Design symbols 4.1.3*

e = weld efficiency factor, *see Pt 15, Ch 1, 4.1 Design symbols 4.1.1*.

p = design pressure, in MPa, *see Pt 15, Ch 1, 4.2 Design pressure*

p_t = hydraulic test pressure, in MPa

t = the minimum thickness of a straight pipe, in mm, including corrosion allowance and negative tolerance, where applicable

t_b = the minimum thickness of a straight pipe to be used for a pipe bend, in mm, including bending allowance, corrosion allowance and negative tolerance, where applicable

D = outside diameter of pipe, in mm, *see Pt 15, Ch 1, 4.1 Design symbols 4.1.2*

R = radius of curvature of a pipe bend at the centre line of the pipe, in mm

T = design temperature, in ^{o}C, *see Pt 15, Ch 1, 4.3 Design temperature 4.3.1*

σ = maximum permissible design stress, in N/mm^2.

4.1.2 The outside diameter, D, is subject to manufacturing tolerances, but these are not to be used in the evaluation of formulae.

4.1.3 The inside diameter, d, is not to be confused with nominal pipe size, which is an accepted designation associated with outside diameters of standard rolling sizes.

4.1.4 The weld efficiency factor, e, is to be taken as 1,0 for seamless and electric resistance or induction welded steel pipes.

4.2 Design pressure

4.2.1 The design pressure, p, is the maximum permissible working pressure and is to be not less than the highest set pressure of the safety valve or relief valve. In systems which have no safety valve or relief valve, the design pressure is to be taken as 1,1 times the maximum working pressure.

4.2.2 The design pressure of piping on the discharge from pumps is to be taken as the pump pressure at full rated speed against a shut valve. Where a safety valve or other protective device is fitted to restrict the pressure to a lower value than the shut valve load, the design pressure is to be the highest set pressure of the device.

4.2.3 For design pressure of steering system components and piping, *see Pt 14 Steering Systems*.

4.3 Design temperature

4.3.1 The design temperature is to be taken as the maximum temperature of the internal fluid, but in no case is it to be less than 50°C.

■ *Section 5*
Carbon and low alloy steels

5.1 General

5.1.1 The minimum thickness of steel pipes is to be determined by the formulae given in *Pt 15, Ch 1, 5.1 General 5.1.2* and *Pt 15, Ch 1, 5.1 General 5.1.3* except that in no case is it to be less than that shown in *Table 1.5.1 Minimum thickness for steel pipes*.

5.1.2 The minimum thickness, t, of straight steel pressure pipes is to be determined by the following formula:

$$t = \left(\frac{pD}{20\,\sigma\,\mathrm{e} + p} + c\right)\frac{100}{100 - a}\ mm$$

where symbols are as defined in *Pt 15, Ch 1, 4.1 Design symbols 4.1.1*

c is obtained from *Table 1.5.2 Values of corrosion allowance (c) for steel pipes* , *see also Pt 15, Ch 1, 5.1 General 5.1.4*

σ may be obtained directly from *Table 1.5.3 Carbon and carbon-manganese steel pipes* or from the formula given in *Pt 15, Ch 1, 5.1 General 5.1.6*.

5.1.3 The minimum thickness t_b, of a straight steel pipe to be used for a pipe bend is to be determined by the following formula, except where it can be demonstrated that the use of a thickness less than t_b would not reduce the thickness below t at any point after bending:

$$t_b = \left[\left(\frac{pD}{20\,\sigma\,e + p}\right)\left(1 + \frac{D}{2,5R}\right) + c\right]\frac{100}{100 - a}\ \mathrm{mm}$$

where symbols are as defined in *Pt 15, Ch 1, 4.1 Design symbols 4.1.1*.

c and σ are obtained as in *Pt 15, Ch 1, 5.1 General 5.1.2*

In general, R is to be not less than $3D$.

Table 1.5.1 Minimum thickness for steel pipes

External diameter *D* mm	Minimum pipe thickness mm
10,2 - 12	1,6
13,5 - 19	1,8
20 - 44,5	2,0
48,3 - 63,5	2,3
70 - 82,5	2,6
88,9 - 108	2,9
114,3 - 127	3,2
133 - 139,7	3,6

152,4 - 168,3	4,0
177,8 and over	4,5

Note 1. The thickness of air, overflow and sounding pipes for structural tanks is to be not less than 4,5 mm.

Note 2. The thickness of bilge, ballast and general sea water pipes is to be not less than 4,0 mm.

Note 3. The thickness of bilge, air, overflow and sounding pipes through ballast and fuel oil tanks, ballast lines through fuel oil tanks and fuel oil lines through ballast tanks is to be not less than 6,3 mm.

Note 4. For air, bilge, ballast, fuel oil, overflow, sounding, and venting pipes as mentioned in Notes 1 to 3, where the pipes are efficiently protected against corrosion the thickness may be reduced by not more than 1 mm.

Note 5. For air and sounding pipes the minimum thickness applies to the part of the pipe outside the tank but not exposed to weather. The section of pipe exposed to weather may be required to be suitably increased in thickness in accordance with statutory and loadline requirements as applicable.

5.1.4 For pipes passing through tanks, where the thickness has been calculated in accordance with *Pt 15, Ch 1, 5.1 General 5.1.2* or *Pt 15, Ch 1, 5.1 General 5.1.3*, an additional corrosion allowance is to be added to take account of external corrosion; the addition will depend on the external medium and the value is to be in accordance with *Table 1.5.2 Values of corrosion allowance (c) for steel pipes* .

Table 1.5.2 Values of corrosion allowance (*c*) for steel pipes

Piping service	*c*, in mm
Saturated steam systems	0,8
Compressed air systems	1,0
Hydraulic oil systems	0,3
Lubricating oil systems	0,3
Fuel oil systems	1,0
Refrigerating plants	0,3
Fresh water systems	0,8
Sea-water systems in general	3,0

5.1.5 Where the pipes are efficiently protected against corrosion, the corrosion allowance, *c*, may be reduced by not more than 50 per cent.

5.1.6 The maximum permissible design stress, σ, is to be taken as the lowest of the following values:

$$\sigma = \frac{E_t}{1,6}$$

$$\sigma = \frac{R_{20}}{2,7}$$

$$\sigma = \frac{S_R}{1,6}$$

where

E_t = specified minimum lower yield or 0,2 per cent proof stress at the design temperature

where

R_{20} = specified minimum tensile strength at ambient temperature

S_R = average stress to produce rupture in 100 000 hours at the design temperature

Values of E_t, R_{20} and S_R may be obtained from *Ch 6 Steel Pipes and Tubes*of the Rules for Materials. Intermediate values may be obtained by interpolation.

5.1.7 Steel stub pipes between the shell plating and the sea valve are to be of short rigid construction, adequately supported and of substantial thickness.

Table 1.5.3 Carbon and carbon-manganese steel pipes

Specified minimum tensile strength, N/mm^2	Maximum permissible design stress, N/mm^2												
	Maximum design temperature, °C												
	50	100	150	200	250	300	350	400	410	420	430	440	450
320	107	105	99	92	78	62	57	55	55	54	54	54	49
360	120	117	110	103	91	76	69	68	68	68	64	56	49
410	136	131	124	117	106	93	86	84	79	71	64	56	49
460	151	146	139	132	122	111	101	99	98	85	73	62	53
490	160	156	148	141	131	121	111	109	98	85	73	62	53

5.2 Steel pipe joints

5.2.1 Joints in steel pipelines may be made by:

- Welded-on bolted flanges, *see Pt 15, Ch 1, 5.3 Welded-on flanges, butt welded joints and fabricated branch pieces*.
- Butt welds between pipes and between pipes and valve chests, *see Pt 15, Ch 1, 5.3 Welded-on flanges, butt welded joints and fabricated branch pieces*.
- Threaded connections, *see Pt 15, Ch 1, 5.4 Fittings having threaded end connections*.
- Threaded sleeve joints and threaded couplings, *see Pt 15, Ch 1, 5.5 Threaded sleeve joints and threaded couplings*.
- Socket weld joints, *see Pt 15, Ch 1, 5.6 Socket weld joints*.
- Welded sleeve joints, *see Pt 15, Ch 1, 5.7 Welded sleeve joints*.
- Mechanical couplings, *see Pt 15, Ch 1, 5.8 Other mechanical couplings*.
- Special types of joints that have been shown to be suitable for the design conditions. Details are to be submitted for consideration.

5.2.2 All welding of pipes is to be in accordance with the requirements specified in *Ch 13 Requirements for Welded Construction* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2021*.

5.2.3 Where pipes are joined by welding a suitable number of flanged joints are to be provided at suitable positions to facilitate installation and removal for maintenance.

5.2.4 Where welded pipes are protected against corrosion then the corrosion protection is to be applied after welding or the corrosion protection is to be made good in way of the weld damaged area.

5.2.5 Where it is not possible to make good the corrosion protection of the weld damaged area, then the pipe is to be considered to have no corrosion protection.

5.2.6 Where backing rings are used for welding pipes, then the effect of the flow obstruction of the backing ring and erosion/ crevice corrosion of the backing ring is to be taken into account.

5.2.7 Piping with joints is to be adequately adjusted, aligned and supported. Supports or hangers are not to be used to force alignment of piping at the point of connection.

5.3 Welded-on flanges, butt welded joints and fabricated branch pieces

5.3.1 The dimensions and material of flanges and bolting, and the pressure-temperature rating of bolted flanges in pressure pipelines, in accordance with National or other established standards will be accepted.

5.3.2 The types of welded-on flanges are to be suitable for the pressure, temperature and service for which the pipes are intended.

5.3.3 Typical examples of welded-on flange attachments are shown in *Figure 1.5.1 Typical examples of welded flange connections*, and limiting design conditions for flange types (a) to (f) are shown in *Table 1.5.4 Limiting design conditions for flange types*.

5.3.4 Welded-on flanges are not to be a tight fit on the pipes. The maximum clearance between the bore of the flange and the outside diameter of the pipe is to be 3 mm at any point, and the sum of the clearances diametrically opposite is not to exceed 5 mm.

5.3.5 Where butt welds are employed in the attachment of flange type (a), in pipe-to-pipe joints or in the construction of branch pieces, the adjacent pieces are to be matched at the bores. This may be effected by drifting, roller expanding or machining, provided that the pipe wall is not reduced below the designed thickness. If the parts to be joined differ in wall thickness, the thicker wall is to be gradually tapered to the thickness of the thinner at the butt joint. The welding necks of valve chests are to be sufficiently long to ensure that the valves are not distorted as the result of welding and subsequent heat treatment of the joints.

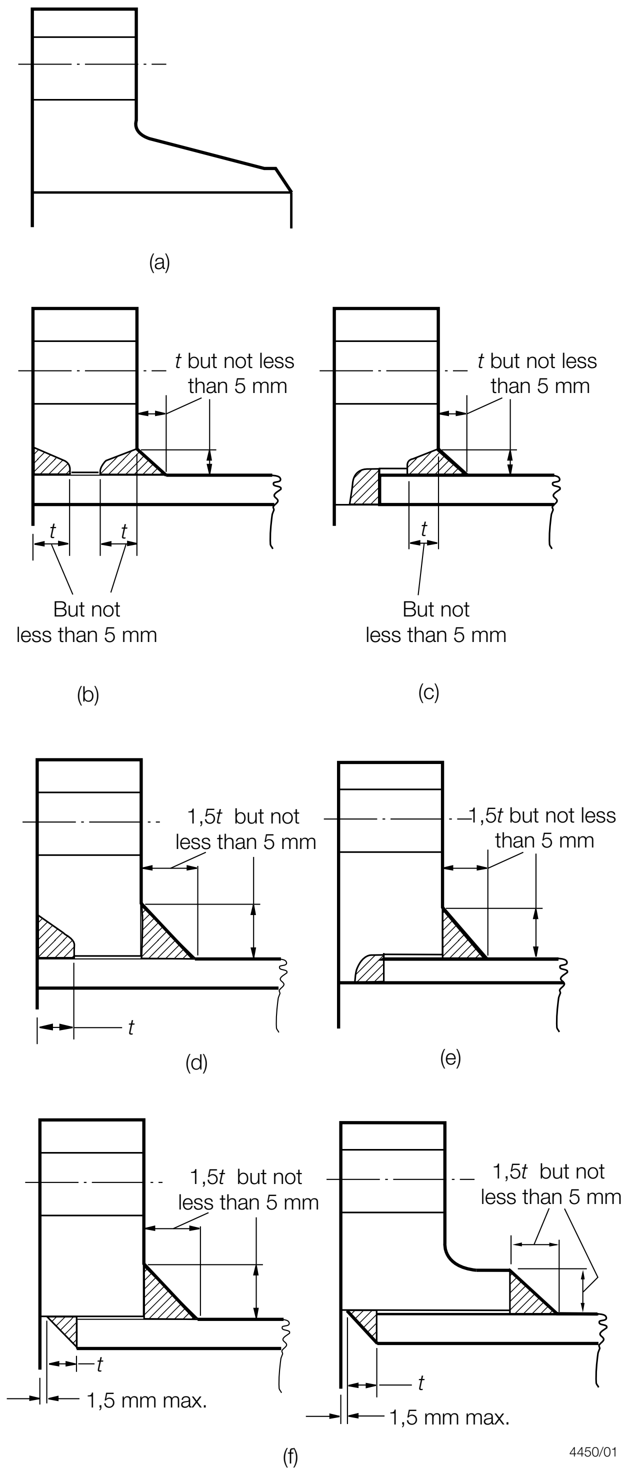


Figure 1.5.1 Typical examples of welded flange connections

5.3.6 Where backing rings are used with flange type (a) they are to fit closely to the bore of the pipe and should be removed after welding. The rings are to be made of the same material as the pipes or of mild steel having a sulphur content not greater than 0,05 per cent.

5.3.7 Branches may be attached to pressure pipes by means of welding provided that the pipe is reinforced at the branch by a compensating plate or collar or other approved means, or alternatively that the thickness of pipe and branch are increased to maintain the strength of the pipe. These requirements also apply to fabricated branch pieces.

Table 1.5.4 Limiting design conditions for flange types

Flange type	Maximum pressure	Maximum temperature	Maximum pipe o.d.	Minimum pipe bore
		°C	mm	mm
(a)	Pressure-temperature ratings to be in accordance with a recognised standard	No restriction	No restriction	No restriction
(b)	Pressure-temperature ratings to be in accordance with a recognised standard	No restriction	168,3 for alloy steels*	No restriction
(c)	Pressure-temperature ratings to be in accordance with a recognised standard	No restriction	168,3 for alloy steels*	75
(d)	Pressure-temperature ratings to be in accordance with a recognised standard	425	No restriction	No restriction
(e)	Pressure-temperature ratings to be in accordance with a recognised standard	425	No restriction	75
(f)	Pressure-temperature ratings to be in accordance with a recognised standard	425	No restriction	No restriction
* No restriction for carbon steels				

5.4 Fittings having threaded end connections

5.4.1 Fittings such as valves, strainers and similar components having threaded end connections may be used in piping systems subject to the restrictions given in *Pt 15, Ch 1, 5.5 Threaded sleeve joints and threaded couplings* for threaded sleeve joints and threaded couplings.

5.4.2 In piping systems conveying flammable or toxic liquids, consideration will be given to instrumentation fittings having threaded connections with suitable sealing arrangements up to a size of DN15.

5.5 Threaded sleeve joints and threaded couplings

5.5.1 Threaded sleeve joints and threaded couplings in accordance with National or other established standards may be used with carbon steel pipes within the limits given in *Table 1.5.5 Limiting design conditions for threaded sleeve joints and threaded couplings*. Such joints are not to be used in piping systems where fatigue, severe erosion or crevice corrosion is expected to occur or where flammable or toxic liquids are conveyed.

Table 1.5.5 Limiting design conditions for threaded sleeve joints and threaded couplings

Thread type	Outside pipe diameter, in mm		
	Class I	Class II	Class III
Tapered thread	<33,7	<60,3	<60,3
Parallel thread	-	-	<60,3

KEY
- Application is not allowed

5.6 Socket weld joints

5.6.1 Socket weld joints may be used in Class III systems with carbon steel pipes of any outside diameter. Socket weld fittings are to be of forged steel and the material is to be compatible with the associated piping. In particular cases, socket weld joints may be permitted for piping systems of Class I and II having outside diameter not exceeding 88,9 mm. Such joints are not to be used where fatigue, severe erosion or crevice corrosion is expected to occur or where toxic liquids are conveyed *See also Pt 15, Ch 4, 7.3 Welded-on flanges, butt welded joints and fabricated branch pieces 7.3.9*.

5.6.2 The thickness of the socket weld fittings is to meet the requirements of *Pt 15, Ch 1, 5.1 General 5.1.3* but is to be not less than 1,42 times the nominal thickness of the pipe or tube tube in order to satisfy the throat thickness requirement in *Pt 15, Ch 1, 5.6 Socket weld joints 5.6.3*. The diametrical clearance between the outside diameter of the pipe and the bore of the fitting is not to exceed 0,8 mm, and a gap of approximately 1,5 mm is to be provided between the end of the pipe and the bottom of the socket. *See also Ch 13, 5.2 Manufacture and workmanship 5.2.9* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2021*.

5.6.3 The leg lengths of the fillet weld connecting the pipe to the socket weld fitting are to be such that the throat dimension of the weld is not less than the nominal thickness of the pipe or tube.

5.6.4 As an alternative to the general dimensional requirements in *Pt 15, Ch 1, 5.6 Socket weld joints 5.6.2* and *Pt 15, Ch 1, 5.6 Socket weld joints 5.6.3*, consideration will be given to socket weld joints in accordance with a recognised National or International Standard.

5.7 Welded sleeve joints

5.7.1 Welded sleeve joints may be used with carbon steel pipes in Class III systems only, subject to the restrictions given in *Pt 15, Ch 1, 5.6 Socket weld joints 5.6.1* for socket weld joints.

5.7.2 The thickness of the sleeve is to satisfy the requirements of *Pt 15, Ch 1, 5.1 General 5.1.2* and *Table 1.5.1 Minimum thickness for steel pipes* but is to be not less than 1,42 times the nominal thickness of the pipe in order to satisfy the throat thickness requirement in *Pt 15, Ch 1, 5.7 Welded sleeve joints 5.7.3*. The radial clearance between the outside diameter of the pipe and the internal diameter of the sleeve is not to exceed 1 mm for pipes up to a nominal diameter of 50 mm, 2 mm for pipes up to a nominal diameter of 200 mm and 3 mm for pipes of larger nominal diameter. The pipe ends are to be separated by a clearance of approximately 2 mm at the centre of the sleeve.

5.7.3 The sleeve material is to be compatible with the associated piping and the leg lengths of the fillet weld connecting the pipe to the sleeve are to be such that the throat dimension of the weld is not less than the nominal thickness of the pipe or tube.

5.7.4 The minimum length of the sleeve is to conform to the following formula:

$$L_{si} = 0{,}14D + 36\text{mm}$$

where

L_{si} is the length of the sleeve
D is defined in *Pt 15, Ch 1, 4.1 Design symbols 4.1.1*

5.7.5 As an alternative to the general dimensional requirements in *Pt 15, Ch 1, 5.7 Welded sleeve joints 5.7.2* to *Pt 15, Ch 1, 5.7 Welded sleeve joints 5.7.4*, consideration will be given to welded sleeve joints in accordance with a recognised National or International Standard.

5.7.6 Welded sleeve joints may be used in piping systems for the storage, distribution and utilisation of oil fuel, lubricating or other flammable oil systems in machinery spaces provided they are located in readily visible and accessible positions.

5.7.7 Welded sleeve joints are not to be used in bilge pipes in way of deep tanks.

5.7.8 Welded sleeve joints are not to be used below the bulkhead deck in scupper pipes as detailed in *Pt 3, Ch 4, 9.4 Scupper arrangements 9.4.5* unless the scupper pipes are provided with an automatic non-return valve at the shell. Where this is not practical, welded sleeve joints may be accepted provided that they are kept to a minimum and located as close as possible to the underside of the bulkhead deck.

5.8 Other mechanical couplings

5.8.1 Pipe unions, compression couplings, or slip-on joints, as shown in *Figure 1.5.2 Examples of mechanical joints (Part 1)* and *Figure 1.5.3 Examples of mechanical joints (Part 2)*, may be used if Type Approved for the service conditions and the intended application. The Type Approval is to be based on the results of testing of the actual joints. The acceptable use for each service is indicated in *Table 1.5.6 Application of mechanical joints* and dependence upon the Class of piping, with limiting pipe dimensions, is indicated in *Table 1.5.7 Application of mechanical joints depending on class of piping*.

5.8.2 Where the application of mechanical joints results in a reduction in pipe wall thickness due to the use of bite type rings or other structural elements, this is to be taken into account in determining the minimum wall thickness of the pipe to withstand the design pressure.

5.8.3 Materials of mechanical joints are to be compatible with the piping material and internal and external media.

5.8.4 Mechanical joints for pressure pipes are to be tested to a burst pressure of 4 times the design pressure. For design pressures above 200 bar the required burst pressure will be specially considered.

5.8.5 Mechanical joints, which in the event of damage could cause fire or flooding, are not to be used in piping sections directly connected to the ship’s side below the bulkhead deck of passenger ships and freeboard deck of cargo ships or tanks containing flammable fluids.

5.8.6 Mechanical joints are to be designed to withstand internal and external pressure as applicable and where used in suction lines are to be capable of operating under vacuum.

5.8.7 The number of mechanical joints in flammable fluid systems is to be kept to a minimum. In general, flanged joints are to conform to a recognised standard.

5.8.8 Generally, slip-on joints are not to be used in pipelines in cargo holds, tanks, and other spaces which are not easily accessible. Application of these joints inside tanks may only be accepted where the medium conveyed is the same as that in the tanks.

5.8.9 Usage of slip type slip-on joints as the main means of pipe connection is not permitted except for cases where compensation of axial pipe deformation is necessary.

5.8.10 Restrained slip-on joints are permitted in steam pipes with a design pressure of 10 bar or less on the weather decks of oil and chemical tankers to accommodate axial pipe movement, *see Pt 15, Ch 2, 2.2 Provision for expansion*.

5.8.11 Mechanical joints are to be tested in accordance with the test requirements of LR’s Type Approval Test Specification Number 2, as relevant to the service conditions and the intended application. The programme of testing is to be agreed with LR.

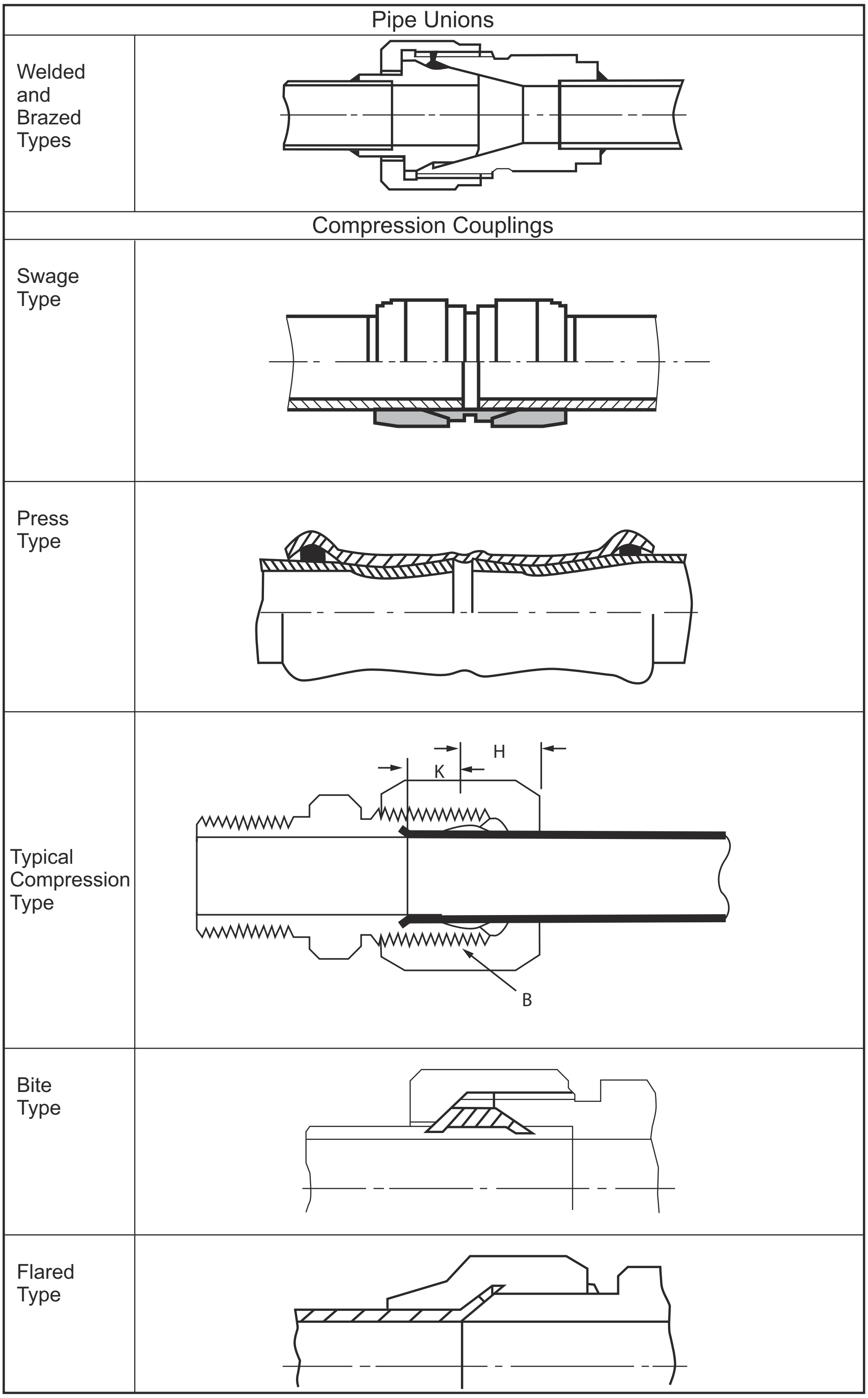


Figure 1.5.2 Examples of mechanical joints (Part 1)

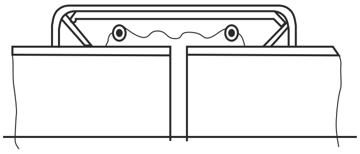
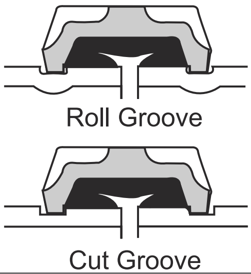
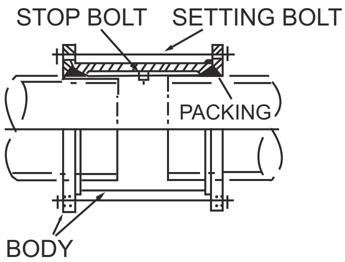
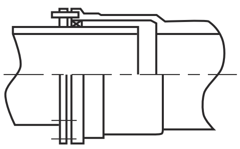
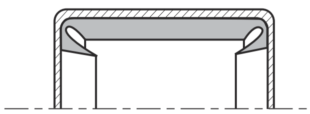
Slip-on Joints	
Grip Type	
Machine Grooved Type	
SlipType	  

Figure 1.5.3 Examples of mechanical joints (Part 2)

Table 1.5.6 Application of mechanical joints

Systems	Type of connections		
	Pipe unions	Compression couplings	Slip-on joints
Flammable fluids (Flash point > 60°)			
Fuel oil lines *see* Notes 2 & 3	+	+	+
Lubricating oil lined *see* Notes 2 & 3	+	+	+
Hydraulic oil *see* Notes 2 & 3	+	+	+
Sea-water			
Bilge lines *see* Note 1	+	+	+
Water filled fire-extinguishing systems, e.g. sprinkler systems *see* Note 3	+	+	+
Non-water filled fire-extinguishing systems, e.g. foam, drencher systems *see* Note 3	+	+	+
Fire main and (not permanently filled) *see* Note 3	+	+	+
Ballast system *see* Note 1	+	+	+
Cooling water system *see* Note 1	+	+	+
Tank cleaning services	+	+	+
Non-essential systems	+	+	+
Fresh water			
Cooling water system *see* Note 1	+	+	+
Condensate return *see* Note 1	+	+	+
Non-essential systems	+	+	+
Sanitary/Drains/Scuppers			
Deck drains (internal) *see* Note 4	+	+	+
Sanitary drains	+	+	+
Scuppers and discharge (overboard)	+	+	—
Sounding/vent			
Water tanks/Sewage tanks/Dry spaces	+	+	+
Oil tanks (f.p.> 60°C) *see* Note 2 & 3	+	+	+
Miscellaneous			
Starting/Control air *see* Note 1	+	+	—
Service air (non-essential)	+	+	+
Brine	+	+	+
CO_2 system *see* Note 1	+	+	—

Steam	+	+	+ *see* Note 5
KEY + Application is allowed — Application is not allowed			
Note 1. Mechanical joints that include any components which readily deteriorate in case of fire, are to be of an approved fire-resistant type when fitted in machinery spaces of category A. Mechanical couplings fitted on the 'bilge main' in machinery spaces of category A are to be of steel or equivalent material. Note 2. Slip-on joints are not accepted in side machinery spaces of category A or accommodation spaces. They may be accepted in other machinery spaces provided the joints are located in easily visible and accessible positions. Note 3. Mechanical joints are to be of an approved fire-resistant type except when they are fitted on open decks having little or no fire risk as defined in SOLAS II-2/Reg. 9.2.3.3.2.2(10). Note 4. Mechanical joints are only permitted above bulkhead deck of passenger ships and freeboard deck of cargo ships. Note 5. *See* Pt 15, Ch 1, 5.8 Other mechanical couplings 5.8.10.			

Table 1.5.7 Application of mechanical joints depending on class of piping

Types of joints	Classes of piping systems		
	Class I	Class II	Class III
Pipe unions			
Welded and brazed type	+(OD ≤ 60,3 mm)	+(OD ≤ 60,3 mm)	+
Compression couplings			
Swage type	+	+	+
Bite type	+(OD ≤ 60,3 mm)	+(OD ≤ 60,3 mm)	+
Typical compression type	+(OD≤ 60,3mm)	+(OD≤ 60,3mm)	+
Flared type	+(OD ≤ 60,3 mm)	+(OD ≤ 60,3 mm)	+
Press type	–	–	+
Slip-on joints			
Machine grooved type	+	+	+
Grip type	–	+	+
Slip type	–	+	+
KEY + Application is allowed – Application is not allowed			

Section 6
Copper and copper alloys

6.1 General

6.1.1 Copper and copper alloy pipes are acceptable for a wide range of services, including bilge pipework and where non heat-sensitive material is required.

6.1.2 The maximum permissible service temperature of copper and copper alloy pipes, valves and fittings is not to exceed 200ºC for copper and aluminium brass, and 300ºC for copper-nickel. Cast bronze valves and fittings complying with the requirements of *Ch 9 Copper Alloys* of the Rules for Materials may be accepted up to 260ºC.

6.1.3 The minimum thickness, *t*, of straight copper and copper alloy pipes is to be determined by the following formula but is not to be less than that shown in *Table 1.6.1 Minimum thickness for copper and copper alloy pipes*:

$$t = \left(\frac{pD}{20\,\sigma\; + p} + c\right)\frac{100}{100 - a}\;mm$$

= where symbols are as defined in *Pt 15, Ch 1, 4.1 Design symbols 4.1.1*

c = 0,8 mm for copper, aluminium brass, and copper-nickel alloys where the nickel content is less than 10 per cent

= 0,5 mm for copper-nickel alloys where the nickel content is 10 per cent or greater

= 0 where the media are non-corrosive relative to the pipe material

σ may be obtained from *Table 1.6.2 Copper and copper alloy pipes*.

Intermediate values may be obtained by linear interpolation.

Table 1.6.1 Minimum thickness for copper and copper alloy pipes

Standard pipe sizes (outside diameter)			Minimum overriding nominal thickness	
			Copper	Copper alloy
8	to	10	1,0	0,8
12	to	20	1,2	1,0
25	to	44,5	1,5	1,2
50	to	76,1	2,0	1,5
88,9	to	108	2,5	2,0
133	to	159	3,0	2,5
193,7	to	267	3,5	3,0
273	to	457,2	4,0	3,5
508	and	over	4,5	4,0

Table 1.6.2 Copper and copper alloy pipes

Pipe material	Condition of supply	Specified minimum tensile strength N/mm^2	Permissible stress, N/mm^2										
			Maximum design temperature, ºC										
			50	75	100	125	150	175	200	225	250	275	300
Copper	Annealed	220	41,2	41,2	40,2	40,2	34,3	27,5	18,6	-	-	-	-
Aluminium brass	Annealed	320	78,5	78,5	78,5	78,5	78,5	51,0	24,5	-	-	-	-

90/19 Copper-nickel iron	Annealed	270	68,6	68,6	67,7	65,7	63,7	61,8	58,8	55,9	52,0	48,1	44,1
70/30 Copper-nickel	Annealed	360	81,4	79,4	77,5	75,5	73,5	71,6	69,6	67,7	65,7	63,7	61,8

6.1.4 The minimum thickness t_b, of a straight seamless copper or copper alloy pipe to be used for a pipe bend is to be determined by the formula below, except where it can be demonstrated that the use of a thickness less than t_b would not reduce the thickness below t at any point after bending:

$$t_{\text{b}} = \left[\left(\frac{pD}{20\,\sigma + p}\right)\left(1 + \frac{D}{2,5R}\right) + c\right]\frac{100}{100 - a}\ \text{mm}$$

where symbols are as defined in *Pt 15, Ch 1, 4.1 Design symbols 4.1.1*.

c and σ are obtained as in *Pt 15, Ch 1, 6.1 General 6.1.3*.

in general, R is to be not less than 3D.

6.1.5 Pipes are to be seamless, and branches are to be provided by cast or stamped fittings, pipe pressing or other approved fabrications.

6.1.6 Brazing and welding materials are to be suitable for the operating temperature and for the medium being carried.

6.1.7 Where silver brazing is used, strength is to be obtained by means of the bond in a capillary space over the whole area of the mating surfaces. A fillet braze at the back of the flange or at the face is undesirable. The alloy used for silver brazing is to contain not less than 49 per cent silver.

6.1.8 The use of copper-zinc brazing alloy is not permitted.

6.2 Heat treatment

6.2.1 Pipes which have been hardened by cold bending are to be suitably heat treated on completion of manufacture and prior to being tested by hydraulic pressure. Copper pipes are to be annealed and copper alloy pipes are to be either annealed or stress relief heat treated.

■ *Section 7* Cast iron

7.1 General

7.1.1 Grey cast iron valves and fittings will, in general, be accepted in Class III piping systems except as stated in *Pt 15, Ch 1, 7.1 General 7.1.5*. Grey cast iron valves and fittings may be accepted in the Class II steam systems referred to in *Table 1.3.1 Maximum pressure and temperature conditions for Class II and III piping systems* but the design pressure or temperature is not to exceed 13 bar or 220°C, respectively.

7.1.2 Spheroidal or nodular graphite iron castings for valves and fittings in Class II and Class III piping systems are to be made in a grade having a specified minimum elongation not less than 12 per cent on a gauge length of $5,65\sqrt{S_o}$, where S_o is the actual cross-sectional area of the test piece.

7.1.3 Proposals for the use of this material in Class I piping systems will be specially considered, but in no case is the material to be used in systems where the design temperature exceeds 350°C.

7.1.4 Where the elongation is less than the minimum required by 7.1.2, the material is, in general, to be subject to the same limitations as grey cast iron.

7.1.5 Grey cast iron is not to be used for the following:

- Valves and fittings for boiler blow-down systems and other piping systems subject to shock or vibration.
- Shell valves and fittings, *see Pt 15, Ch 2, 3.1 Construction*.
- Valves fitted on the collision bulkhead.
- Valves fitted to tanks containing flammable oil under static pressure.
- Valve chests and fittings for starting air systems, *see Pt 10, Ch 1, 8.5 Starting air pipe systems and safety fittings 8.5.3*.

Section 8
Plastic pipes

8.1 General

8.1.1 Proposals to use plastic pipes in shipboard piping systems will be considered in relation to the properties of the materials, the operating conditions, the intended service and location. Details are to be submitted for approval. Special consideration will be given to any proposed service for plastic pipes not mentioned in these Rules.

8.1.2 Plastic pipes and fittings will, in general, be accepted in Class III piping systems. Proposals for the use of plastic in Class I and Class II piping systems will be specially considered.

8.1.3 For Class I, Class II and any Class III piping systems for which there are Rule requirements, the pipes are to be of a type which has been approved by LR.

8.1.4 For domestic and similar services where there are no Rule requirements, the pipes need not be of a type which has been approved by LR. However, the fire safety aspects, as referenced in *Pt 15, Ch 1, 8.4 Fire performance criteria* and *Pt 15, Ch 1, 8.5 Additional fire performance criteria applicable to Special Service Craft*, are to be considered.

8.1.5 The use of plastic pipes may be restricted by statutory requirements of the National Authority of the country in which the vessel is to be registered.

8.2 Design and performance criteria

8.2.1 Pipes and fittings are to be of robust construction and are to comply with an acceptable National or International Standard, consistent with the intended use. Particulars of pipes, fittings and joints are to be submitted for consideration.

8.2.2 The design and performance criteria of all piping systems, independent of service or location, are to meet the requirements of *Pt 15, Ch 1, 8.3 Design strength*.

8.2.3 Depending on the service and location, the fire safety aspects, such as fire endurance, flame spread, smoke generation, toxicity and fire protection coatings, are to meet the requirements of *Pt 15, Ch 1, 8.4 Fire performance criteria* and *Pt 15, Ch 1, 8.5 Additional fire performance criteria applicable to Special Service Craft*.

8.2.4 Plastic piping, connections and fittings are to be electrically conductive when:

(a) carrying fluids capable of generating electrostatic charges; or
(b) passing through hazardous zones and spaces, regardless of the fluid being conveyed.

Suitable precautions against the build-up of electrostatic charges are to be provided in accordance with the requirements of *Pt 15, Ch 1, 8.6 Electrical conductivity*.

8.3 Design strength

8.3.1 The strength of pipes is to be determined by hydrostatic pressure tests to failure on representative sizes of pipe. The strength of fittings is to be not less than the strength of the pipes.

8.3.2 The nominal internal pressure, p_{Ni}, of the pipe is to be determined by the lesser of the following:

$p_{Ni} < 2{,}5\ p_{st}$

$p_{Ni} < 4\ p_{lt}$

where

p_{st} = short term hydrostatic test failure pressure, in MPa

p_{lt} = long term hydrostatic test failure pressure (100 000 hours), in MPa

Failure pressures obtained over a reduced period and extrapolated in accordance with a recognised National or International Standard will be specially considered.

8.3.3 In service, the pipe is not to be subjected to a pressure greater than p_{Ni}.

8.3.4 The nominal external pressure, p_{Ne}, of the pipe, defined as the maximum total of internal vacuum and external static pressure head to which the pipe may be subjected, is to be determined by the following:

$$p_{Ne} \le \frac{p_{col}}{3}$$

where

p_{col} = pipe collapse pressure, in MPa

8.3.5 p_{col} is not to be less than 3 bar.

8.3.6 Piping is to meet the requirements of *Pt 15, Ch 1, 8.3 Design strength* over the range of service temperature which will be experienced in service.

8.3.7 High temperature limits and pressure reductions relative to nominal pressures are to be in accordance with a recognised standard, but in each case the maximum working temperature is to be at least 20°C lower than the minimum temperature for deflection under load of the resin or plastic material without reinforcement. The minimum heat distortion temperature is not to be less than 80°C. *See also Ch 14, 4 Plastic pipes and fittings* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2021*.

8.3.8 Where it is proposed to use plastic piping in low temperature services, design strength testing is to be made at a temperature 10°C lower than the minimum working temperature.

8.3.9 The selection of plastic materials for piping is to take account of other factors such as impact resistance, ageing, fatigue, erosion resistance, fluid absorption and material compatibility such that the design strength of the piping is not reduced below that required by these Rules.

8.3.10 Design strength values may be verified experimentally or by a combination of testing and calculation methods.

8.4 Fire performance criteria

8.4.1 Where a fire protective coating of pipes and fittings is necessary for achieving the fire endurance standards required, the coating is to be resistant to products likely to come into contact with the piping and be suitable for the intended application.

8.4.2 The materials used for plastic pipes, except those fitted on open decks and within tanks, cofferdams, void spaces, pipe tunnels and ducts are to have low flame spread characteristics.

8.4.3 The materials used for plastic pipes within accommodation, service and control spaces are not to be capable of producing excessive quantities of smoke and toxic products that may be a hazard to personnel within those spaces.

8.5 Additional fire performance criteria applicable to Special Service Craft

8.5.1 Where plastic pipes are used in systems essential to the safe operation of the vessel, or for containing combustible liquids or sea water where leakage or failure could result in fire or in the flooding of watertight compartments, the pipes and fittings, including couplings with flexible internal seals, are to be of a type which has been fire endurance tested in accordance with the requirements of *Table 1.8.1 Fire endurance requirements*.

Table 1.8.1 Fire endurance requirements

	Location								
	A	B	C	D	E	F	G	H	I
FLAMMABLE LIQUIDS (f.p. > 60°C)									
1 Fuel oil	X	X	X	X	0	0	0	L1	L1
2 Lubricating oil	X	X	X	X	X	N/A	0	L1	L1
3 Hydraulic oil	X	X	X	X	0	0	0	L1	L1
SEA WATER [1]									
4 Bilge main and branches	L1[4]	L1[4]	X	X	0	0	0	N.A	L1
5 Fire main and water spray	L1	L1	X	N/A	N/A	0	0	X	L1
6 Foam system	L1W	L1W	L1W	N/A	N/A	N/A	0	L1W	L1W

7 Sprinkler system	L1W	L1W	X	N/A	N/A	0	0	L3	L3
8 Ballast	L3	L3	L3	X	0	0	0	L2W	L2W
9 Cooling water, essential services	L3	L3	N/A	N/A	N/A	0	0	N/A	L2W
10 Non-essential systems	0	0	0	0	0	0	0	0	0
FRESH WATER									
11 Cooling water essential services	L3	L3	N/A	N/A	0	0	0	L3	L3
12 Non-essential systems	0	0	0	0	0	0	0	0	0
ENGINE EXHAUSTS									
13 Main line	0[1]	0[1]	0[1]	0[1]	N/A	N/A	01	N/A	L1
14 Drain line	0[1]	0[1]	0[1]	N/A	N/A	N/A	N/A	N/A	N/A
SANITARY/DRAINS/SCUPPERS									
15 Deck drains (internal)	L1W[2]	L1W[2]	L1W[2]	0	0	0	0	0	0
16 Sanitary drains (internal)	0	0	0	0	0	0	0	0	0
17 Scuppers and discharges (overboard)	0[1,5]	0[1,5]	0[1,5]	0[1,5]	0	0	0	0[1,5]	0
SOUNDING/AIR									
18 Water tanks/dry spaces	0	0	0	0	0	0	0	0	0 [7]
19 Oil tanks (f.p. > 60°C)	X	X	X	X	0	0	0	X	X
MISCELLANEOUS									
20 Control air	L1[3]	L1[3]	L1[3]	L1[3]	0	0	0	L1[3]	L1[3]
21 Service air (non-essential)	0	0	0	0	0	0	0	0	0
22 Brine	0	0	0	0	N/A	N/A	0	0	0
23 low pressure steam (≤ 7 bar)	L2W	L2W	0[6]	0[6]	0	0	0	0[6]	0[6]
NEW SERVICES									
24 Central vacuum cleaning system	N/A	N/A	N/A	0	N/A	N/A	N/A	N/A	0
25 Exhaust gas cleaning system effluent line	L3[1]	L3[1]	N/A	N/A	N/A	N/A	N/A	L3[1,8] /NA	N/A
26 Urea transfer/supply system (SCR installations)	L1[9]	L1[9]	N/A	N/A	N/A	N/A	N/A	L3[1,8] /NA	0

LOCATION DEFINITIONS		
Location		Definition
A	Machinery spaces of Category A	Machinery spaces of Category A as defined in *Pt 17, Ch 1, 2.4 Ship divisions and spaces 2.4.8*.

B	Other machinery spaces and pump rooms	Spaces, other than Category A machinery spaces, containing propelling machinery, boilers, fuel oil units, internal combustion engines, generators and major electrical machinery, pumps, oil filling stations, refrigerating, stabilising, ventilation and air conditioning machinery and similar spaces, and trunks to such spaces.
C	Special category spaces	Ro-ro spaces and special category spaces as defined in *SOLAS - International Convention for the Safety of Life at Sea Chapter II-2 - Construction - Fire protection, fire detection and fire extinction*/3.14 and *SOLAS - International Convention for the Safety of Life at Sea Chapter II-2 - Construction - Fire protection, fire detection and fire extinction*/3.18.
D	Dry cargo spaces	All spaces other than ro-ro spaces and special category spaces used for the carriage of dry cargo and trunks to such spaces.
E	Fuel oil tanks	All spaces used for fuel oil and trunks to such spaces.
F	Ballast water tanks	All spaces used for ballast water and trunks to such spaces.
G	Cofferdams, voids, etc.	Cofferdams and voids are those empty spaces between two bulkheads separating two adjacent compartments.
H	Accommodation, service	Accommodation spaces, service spaces and control stations as defined in *Pt 17, Ch 1, 2.4 Ship divisions and spaces 2.4.5*, *Pt 17, Ch 1, 2.4 Ship divisions and spaces 2.4.6* and *Pt 17, Ch 1, 2.4 Ship divisions and spaces 2.4.10*.
I	Open decks	Open deck spaces, as defined in *SOLAS - International Convention for the Safety of Life at Sea Chapter II-2 - Construction - Fire protection, fire detection and fire extinction*/26.2.2(5).
ABBREVIATIONS		
L1	*IMO Resolution A.753(18) - Guidelines for the Application of Plastic Pipes on Ships - (adopted on 4 November 1993)Amended by Resolution MSC.313(88)*, as amended by *Resolution MSC.313(88) – Amendments to the Guidelines for the Application of Plastic Pipes on Ships (Resolution A.753(18)) – (Adopted on 26 November 2010)* and *Resolution MSC.399(95) - Amendments to the Guidelines for the Application of Plastic Pipes on Ships (Resolution A.753(18)), as amended by Resolution MSC.313(88) - (Adopted on 5 June 2015)* for a duration of a minimum of one hour without loss of integrity in the dry condition is considered to meet level 1 fire endurance standard (L1). Level 1W – Piping systems similar to Level 1 systems except these systems do not carry flammable fluid or any gas and a maximum 5% flow loss in the system after exposure is acceptable (L1W).	

L2	Level 2. Piping having passed the fire endurance test specified in Appendix 1 of *IMO Resolution A.753(18) - Guidelines for the Application of Plastic Pipes on Ships - (adopted on 4 November 1993)Amended by Resolution MSC.313(88)*, as amended by *Resolution MSC.313(88) – Amendments to the Guidelines for the Application of Plastic Pipes on Ships (Resolution A.753(18)) – (Adopted on 26 November 2010)* and *Resolution MSC.399(95) - Amendments to the Guidelines for the Application of Plastic Pipes on Ships (Resolution A.753(18)), as amended by Resolution MSC.313(88) - (Adopted on 5 June 2015)* for a duration of a minimum of 30 minutes in the dry condition is considered to meet level 2 fire endurance standard (L2). Level 2W – Piping systems similar to Level 2 systems except a maximum 5% flow loss in the system after exposure is acceptable (L2W).
L3	Fire endurance test in wet conditions, 30 minutes, *IMO Resolution A.753(18) - Guidelines for the Application of Plastic Pipes on Ships - (adopted on 4 November 1993)Amended by Resolution MSC.313(88) Appendix 2 - Test Method for Fire Endurance Testing of Water-Filled Plastic Piping*.
0	No fire endurance test required.
N/A	Not applicable.
X	Metallic materials having a melting point greater than 925°C.

Note 1. Remotely controlled valves are to be provided at ship’s side. Valve is to be controlled from outside space. Where the valve is located below the SWL, the operating position is to be above the freeboard deck.

Note 2. For drains serving only the space concerned, ‘0’ may replace ‘L1’.

Note 3. When controlling functions are not required by the Rules or statutory requirements, ‘0’ may replace ‘L1’.

Note 4. For passenger craft, ‘X’ is to replace ‘L1W’.

Note 5. Scuppers serving open decks in positions 1 and 2, as defined in *Regulation 13 - Position of hatchways, doorways and ventilators* of the *Load Lines, 1966/1988 - International Convention on Load Lines, 1966, as Amended by the Protocol of 1988*, should be ‘X’ throughout unless fitted at the upper end with a means of closing capable of being operated from a position above the freeboard deck in order to prevent downflooding. Consideration will be given to the acceptance of other arrangements which provide equivalent protection.

Note 6. For essential services, ‘X’ is to replace ‘0’.

Note 7. Air and sounding pipes are to be located in a sheltered position, and protected from mechanical damage.

Note 8. L3 in service spaces, N/A in accommodation and control spaces.

Note Type Approved plastic piping without fire endurance test (0) is acceptable downstream of the tank valve, provided this valve is metal seated and arranged as fail-to-closed or with quick closing from a safe position outside the space in the event of fire.

Note 10. For Passenger Ships subject to SOLAS II-2, Reg.21.4 (Safe return to Port), plastic pipes for services required to remain operative in the part of the ship not affected by the casualty thresholds, such as systems intended to support safe areas, are to be considered essential services. In accordance with *MSC.1/Circular.1369 – Interim Explanatory Notes for the Assessment of Passenger Ship Systems' Capabilities After a Fire or Flooding Casualty– (22 June 2010)1*, interpretation 12, for Safe Return to Port purposes, plastic piping can be considered to remain operational after a fire casualty if the plastic pipes and fittings have been tested to L1 standard.

8.6 Electrical conductivity

8.6.1 Where a piping system is required to be electrically conductive for the control of static electricity, the resistance per unit length of the pipe, bends, elbows, fabricated branch pieces, etc. is not to exceed 0,1 MΩ/m.

8.6.2 Where a piping system is required to be electrically conductive for the control of static electricity, electrical continuity is to be maintained across the joints and fittings and the system is to be earthed. The resistance to earth from any point in the piping system is not to exceed 1 MΩ. *See also Pt 16, Ch 2, 1.13 Electrical bonding for the control of static electricity*.

8.7 Manufacture and quality control

8.7.1 All materials for plastic pipes and fittings are to be approved by LR, and are in general to be tested in accordance with *Ch 14, 4 Plastic pipes and fittings* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2021*. For pipes and fittings not employing hand lay up techniques, the hydrostatic pressure test required by *Ch 14, 4.9 Hydraulic test* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2021* may be replaced by testing carried out in accordance with the requirements stipulated in a recognised National or International Standard, consistent with the intended use for which the pipe or fittings are manufactured, provided that there is an effective quality system in place complying with the requirements of *Ch 14, 4.4 Quality assurance* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2021* and the testing is completed to the satisfaction of the LR Surveyor.

8.7.2 The material manufacturer's test certificate, based on actual tested data, is to be provided for each batch of material.

8.7.3 Plastic pipes and fittings are to be manufactured at a works approved by LR in accordance with agreed quality control procedures which shall be capable of detecting at any stage (e.g. incoming material, production, finished article, etc.) deviations in the material, product or process.

8.7.4 Plastic pipes are to be manufactured and tested in accordance with *Ch 14, 4 Plastic pipes and fittings* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2021*. For Class III piping systems the pipe manufacturer's test certificate may be accepted in lieu of an LR Certificate and is to be provided for each consignment of pipe.

8.8 Construction and installation

8.8.1 All pipes are to be adequately but freely supported. Suitable provision is to be made for expansion and contraction to take place without unduly straining the pipes.

8.8.2 Pipes may be joined by mechanical couplings or by bonding methods such as welding, laminating and adhesive bonding.

8.8.3 Where bonding systems are used, the manufacturer or installer shall provide a written procedure covering all aspects of installation, including temperature and humidity conditions. The bonding procedure is to be approved by LR.

8.8.4 The person carrying out the bonding is to be qualified. Records are to be available to the Surveyor for each qualified person showing the bonding procedure and performance qualification, together with dates and results of the qualification testing.

8.8.5 Conditions during installation, such as temperature and humidity, which may affect the strength of the finished joints, are to be in accordance with the agreed bonding procedure.

8.8.6 The required fire endurance level of the pipe is to be maintained in way of pipe supports, joints and fittings, including those between plastic and metallic pipes.

8.8.7 Where piping systems are arranged to pass through watertight bulkheads or decks, provision is to be made for maintaining the integrity of the bulkhead or deck by means of metallic bulkhead or deck pieces. The bulkhead or deck pieces are to be of substantial construction and suitably protected against corrosion and so constructed to be of a strength equivalent to the intact bulkhead; attention is drawn to *Pt 15, Ch 1, 8.8 Construction and installation 8.8.1*, details of the arrangements are to be submitted for approval.

8.8.8 Pipes or other fittings attached directly to the plating of tanks and to bulkheads, which are required to be of watertight construction, are to be secured by means of studs screwed through the plating or by tap bolts, and not by bolts passing through clearance holes. Alternatively, the studs or the bulkhead or tank pieces may be welded to the plating.

8.9 Additional requirements for testing plastic pipes for Special Service Craft

8.9.1 Where a piping system is required to be electrically conductive, tests are to be carried out in accordance with *Pt 15, Ch 1, 8.6 Electrical conductivity*.

8.9.2 The hydraulic testing of pipes and fittings is to be in accordance with *Pt 15, Ch 1, 14.1 Hydraulic tests before installation on board*.

8.9.3 In the case of pipes intended for essential services each qualified person is, at the place of construction, to make at least one test joint, representative of each type of joint to be used. The joined pipe section is to be tested to an internal hydrostatic pressure of four times the design pressure of the pipe system and the pressure held for not less than one hour, with no leakage or separation of joints. The bonding procedure test is to be witnessed by the Surveyor.

■ *Section 9*
Austenitic and duplex stainless steels

9.1 General

9.1.1 Stainless steels may be used for a wide range of services.

9.1.2 Austenitic and duplex stainless steels may be suitable for use at elevated temperatures. Application, environment, operating temperature and time at temperature must be considered in the choice of austenitic or duplex stainless steel grade.

9.1.3 For guidance on the use of austenitic and duplex stainless steels in sea water systems, *see Pt 15, Ch 1, 16.3 Steel pipes 16.3.4*.

9.1.4 The minimum thickness of stainless steel pipes is to be determined from the formula given in *Pt 15, Ch 1, 5.1 General 5.1.2* or *Pt 15, Ch 1, 5.1 General 5.1.3*. Values of the 1,0 per cent proof stress and tensile strength of the material for use in the formula in *Pt 15, Ch 1, 5.1 General 5.1.6* may be obtained from *Table 6.5.2 Mechanical properties for acceptance purposes* in Chapter 6 of the Rules for Materials.

9.1.5 In no case is the thickness of stainless steel pipes to be less than that shown in *Table 1.9.1 Minimum thickness for austenitic and duplex stainless steel pipes*.

Table 1.9.1 Minimum thickness for austenitic and duplex stainless steel pipes

Standard pipe sizes (outside diameter)			Minimum nominal thickness
mm		mm	mm
8,0	to	10,0	0,8
10,2	to	17,2	1,0
21,3	to	48,3	1,6
60,3	to	88,9	2,0
114,3	to	168,3	2,3
219,1			2,6
273,0			2,9
323,9	to	406,4	3,6
over	406,4		4,0

Note Diameters and thicknesses according to National or International Standards may be accepted.

9.1.6 Joints in stainless steel pipework may be made by any of the techniques described in *Pt 15, Ch 1, 5.2 Steel pipe joints* to 5.8.

9.1.7 Where pipework is butt welded, this should preferably be accomplished without the use of backing rings, in order to eliminate the possibility of crevice corrosion between the backing ring and pipe.

Section 10
Aluminium alloy

10.1 General

10.1.1 The use of aluminium alloy material in Class III piping systems will be considered in relation to the fluid being conveyed and operating conditions of temperature and pressure.

10.1.2 In general, aluminium alloy may be used for air and sounding pipes for water tanks and dry spaces providing it can be shown that pipe failure will not cause a loss of integrity across watertight divisions. In craft of aluminium construction, aluminium alloy may also be used for air and sounding pipes for fuel oil, lubricating oil and other flammable liquid tanks provided the pipes are suitably protected against the effects of fire.

10.1.3 Aluminium alloy pipes are not to be used in machinery spaces, ro-ro spaces, special category spaces or cargo spaces for conveying fuel oil, lubricating oil or other flammable liquids, or for bilge suction pipework within such spaces.

10.1.4 Aluminium alloy pipes are not acceptable for fire extinguishing pipes unless they are suitably protected against the effect of heat. The use of aluminium alloy with appropriate insulation will be considered when it has been demonstrated that the arrangements provide equivalent structural and integrity properties compared to steel. In open and exposed locations, where the insulation material is likely to suffer from mechanical damage, suitable protection is to be provided.

10.1.5 The minimum thickness of aluminium alloy pipes is to be not less than that shown in *Table 1.10.1 Minimum thickness of aluminium pipes*.

Table 1.10.1 Minimum thickness of aluminium pipes

Nominal pipe size (mm)	Minimum wall thickness (mm)
10	1,7
15	2,1
20	2,1
25	2,8
40	2,8
50	2,8
80	3,0
100	3,0
150	3,4
200	3,8
250 and over	4,2

10.1.6 Design requirements for aluminium pressure pipes for design pressures greater than 7 bar will be specially considered.

10.1.7 Attention is drawn to the susceptibility of aluminium to corrosion in the region of welded connections.

Section 11
Material certificates

11.1 Metallic materials

11.1.1 Materials for Class I and II piping systems and components as defined in *Table 1.3.1 Maximum pressure and temperature conditions for Class II and III piping systems*, also for shell valves and fittings on the collision bulkhead are to be manufactured and tested in accordance with the *Rules for the Manufacture, Testing and Certification of Materials, July 2021*.

11.1.2 Materials for metallic castings and forgings for Class I and II piping systems are to be produced at a works approved by Lloyd's Register (commonly referred to as 'LR') and are to be tested in accordance with the *Rules for the Manufacture, Testing and Certification of Materials, July 2021* (commonly referred to as the Rules for Materials).

11.1.3 Materials for Class III piping systems are to be manufactured and tested in accordance with the requirements of acceptable National Standards.

11.1.4 The Manufacturer's materials test certificate will be accepted for all classes of piping and components in lieu of an LR materials certificate where the maximum design conditions are less than shown in *Table 1.11.1 Maximum conditions for pipes, valves and fittings for which Manufacturer's materials test certificate is acceptable*.

Table 1.11.1 Maximum conditions for pipes, valves and fittings for which Manufacturer's materials test certificate is acceptable

Material	Working temperature ^oC	DN = Nominal Diameter, mm P_w = Working Pressure, bar
Carbon and low alloy steel. Stainless steel. Spheroidal or nodular cast iron.	< 300	$DN < 50$ or $P_w \times DN < 2500$
Copper alloy	< 200	$DN < 50$ or $P_w \times DN < 1500$

11.2 Non-metallic materials

11.2.1 Pipes and fittings intended for applications in Class I, Class II and Class III systems for which there are Rule requirements are to be manufactured in accordance with *Ch 14 Plastics Materials and other Non-Metallic Materials* of the Rules for Materials.

Section 12
Requirements for valves

12.1 General

12.1.1 The design, construction and operational capability of valves are to be in accordance with an acceptable National or International Standard appropriate for the piping system. Where valves are not in accordance with an acceptable Standard, details are to be submitted for consideration.

12.1.2 Valves are to be made of steel, cast iron, copper alloy, or other approved material suitable for the intended purpose.

12.1.3 Valves having isolation or sealing components sensitive to heat are not to be used in spaces where leakage or failure caused by fire could result in fire spread, flooding or the loss of an essential service.

12.1.4 Where valves are required to be capable of being closed remotely in the event of fire, the valves, including their controlgear, are to be of steel construction or of an acceptable fire tested design.

12.1.5 Valves are to be arranged for clockwise closing and are to be provided with indicators showing whether they are open or shut unless this is readily obvious.

12.1.6 Valves are to be so constructed as to prevent the possibility of valve covers or glands being slackened back or loosened when the valves are operated.

12.1.7 Valves and cocks are to be fitted with legible nameplates, and, unless otherwise specifically mentioned in the Rules, the valves and cocks are to be fitted in places where they are at all times readily accessible.

12.1.8 Valves are to be used within their specified pressure and temperature rating for all normal operating conditions, and are to be suitable for the intended purpose.

12.1.9 Valves intended for submerged installation are to be suitable for both internal and external media. Spindle sealing is to prevent ingress of external media at the maximum external pressure head expected in service.

12.1.10 Additional requirements for shell valves are given in *Pt 15, Ch 2, 3 Shell valves and fittings (other than those on scuppers and sanitary discharges)*.

12.2 Valves with remote control

12.2.1 All valves which are provided with remote control are to be arranged for local manual operation, independent of the remote operating mechanism.

12.2.2 In the case of valves which are required by the Rules to be provided with remote control, opening and/or closing of the valves by local manual means is not to render the remote control system inoperable.

12.2.3 For shipside valves and valves on the collision bulkhead, the means for local manual operation are to be permanently attached.

12.3 Resiliently seated valves

12.3.1 Valves, having isolation or sealing components sensitive to heat, are not to be used in spaces where leakage or failure caused by fire could result in fire spread, flooding or loss of an essential service.

12.3.2 Where the valves are of the diaphragm type, they are not acceptable as shut off valves at the shell plating.

12.3.3 Resiliently seated valves are not to be used in main or auxiliary machinery spaces or in other locations having a significant fire risk as branch or direct bilge suction valves or as pump suction valves from the main bilge line (except where the valve is located in the immediate vicinity of the pump and in series with a metal seated non-return valve. The non-return valve is to be fitted on the bilge main side of the resiliently seated valve).

12.3.4 Resiliently seated valves are not acceptable for use in fire water mains unless they have been satisfactorily fire tested.

■ *Section 13*
Flexible hoses

13.1 General

13.1.1 A flexible hose assembly is a short length of metallic or non-metallic hose normally with prefabricated end fittings ready for installation.

13.1.2 For the purpose of approval for the applications in *Pt 15, Ch 1, 13.2 Applications for rubber hoses*, details of the materials and construction of the hoses, and the method of attaching the end fittings together with evidence of satisfactory prototype testing, are to be submitted for consideration.

13.1.3 The use of hose clamps and similar types of end attachments are not be used for flexible hoses in piping systems for steam, flammable media, starting air systems or for sea water systems where failure may result in flooding. In other piping

systems, the use of hose clamps may be accepted where the working pressure is less than 5 bar and provided that there are two clamps at each end connection.

13.1.4 Flexible hoses are to be limited to a length necessary to provide for relative movement between fixed and flexibly mounted items of machinery/equipment or systems.

13.1.5 Flexible hoses are not to be used to compensate for misalignment between sections of piping.

13.1.6 Flexible hose assemblies are not to be installed where they may be subjected to torsional deformation (twisting) under normal operating conditions.

13.1.7 The number of flexible hoses in piping systems mentioned in this section is to be kept to a minimum and to be limited for the purpose stated in *Pt 15, Ch 1, 13.2 Applications for rubber hoses 13.2.1*.

13.1.8 Where flexible hoses are intended for conveying flammable fluids in piping systems that are in close proximity to hot surfaces, electrical installation or other sources of ignition, the risk of ignition due to failure of the hose assembly and subsequent release of fluids is to be mitigated as far as practicable by the use of screens or other suitable protection.

13.1.9 Flexible hoses are to be installed in clearly visible and readily accessible locations.

13.1.10 The installation of flexible hose assemblies is to be in accordance with the manufacturer's instructions and use limitations with particular attention to the following:

(a) Orientation.
(b) End connection support (where necessary).
(c) Avoidance of hose contact that could cause rubbing and abrasion.
(d) Minimum bend radii.

13.1.11 Flexible hoses are to be permanently marked by the manufacturer with the following details:

(a) Hose manufacturer's name or trademark.
(b) Date of manufacture (month/year).
(c) Designation type reference.
(d) Nominal diameter.
(e) Pressure rating.
(f) Temperature rating.

Where a flexible hose assembly is made up of items from different manufacturers, the components are to be clearly identified and traceable to evidence of prototype testing.

13.2 Applications for rubber hoses

13.2.1 Short joining lengths of flexible hoses complying with the requirements of this Section may be used, where necessary, to accommodate relative movement between various items of machinery connected to permanent piping systems. The requirements of this Section may also be applied to temporarily-connected flexible hoses or hoses of portable equipment.

13.2.2 Rubber or plastics hoses, with integral cotton or similar braid reinforcement, may be used in fresh and sea-water cooling systems. In the case of sea-water systems, where failure of the hoses could give rise to the danger of flooding, the hoses are to be suitably enclosed, as indicated in *Pt 15, Ch 2, 2.2 Provision for expansion 2.2.3*.

13.2.3 Rubber hoses, with single, double or more closely woven integral wire braid or other suitable material reinforcement, or convoluted metal pipes with wire braid protection, may be used in bilge, ballast, compressed air, fresh water, sea-water, fuel oil, lubricating oil, Class III steam, hydraulic and thermal oil systems. Flexible hoses of plastics materials for the same purposes, such as Teflon or Nylon, which are unable to be reinforced by incorporating closely woven integral wire braid are to have suitable material reinforcement as far as practicable. Where rubber or plastics hoses are used for fuel oil supply to burners, the hoses are to have external wire braid protection in addition to the integral wire braid. Flexible hoses for use in steam systems are to be of metallic construction.

13.2.4 Flexible hoses are not to be used in high pressure fuel oil injection systems.

13.2.5 The requirements in this Section for flexible hose assemblies are not applicable to hoses intended to be used in fixed fire extinguishing systems.

13.3 Design requirements

13.3.1 Flexible hose assemblies are to be designed and constructed in accordance with recognised National or International Standards acceptable to LR.

13.3.2 Flexible hoses are to be complete with approved end fittings in accordance with manufacturer's specification. End connections which do not have flanges are to comply with *Pt 15, Ch 1, 5.8 Other mechanical couplings* as applicable and each type of hose/fitting combination is to be subject to prototype testing to the same standard as that required by the hose with particular reference to pressure and impulse tests.

13.3.3 Flexible hose assemblies intended for installation in piping systems where pressure pulses and/or high levels of vibration are expected to occur in service, are to be designed for the maximum expected impulse peak pressure and forces due to vibration. The tests required by *Pt 15, Ch 1, 13.4 Testing* are to take into consideration the maximum anticipated in-service pressures, vibration frequencies and forces due to installation.

13.3.4 Flexible hose assemblies constructed of non-metallic materials intended for installation in piping systems for flammable media, and seawater systems where failure may result in flooding, are to be of fire-resistant type. Non-metallic flexible hoses used for sea water systems and flammable media, except fuel oil, installed on open decks having little or no fire risk are not required to be of fire-resistant type. Fire resistance is to be demonstrated by testing to ISO 15540 and ISO 15541.

13.3.5 Flexible hose assemblies are to be suitable for the intended location and application, taking into consideration ambient conditions, compatibility with fluids under working pressure and temperature conditions consistent with the manufacturer's instructions and any other applicable requirements in the Rules.

13.4 Testing

13.4.1 Acceptance of flexible hose assemblies is subject to satisfactory prototype testing. Prototype test programmes for flexible hose assemblies are to be submitted by the manufacturer and are to be sufficiently detailed to demonstrate performance in accordance with the specified standards.

13.4.2 For a particular hose type complete with end fittings, the tests, as applicable, are to be carried out on different nominal diameters for pressure, burst, impulse and fire resistance in accordance with the requirements of the relevant standard. The following standards are to be used as applicable:

(a) ISO 6802 - *Rubber and plastics hoses and hose assemblies with wire reinforcements - Hydraulic impulse test with flexing*.
(b) ISO 6803 - *Rubber or plastics hoses and hose assemblies - Hydraulic pressure impulse test without flexing*.
(c) ISO 15540 - *Ships and marine technology - Fire resistance of hose assemblies - Test methods*.
(d) ISO 15541 - *Ships and marine technology - Fire resistance of hose assemblies - Requirements for test bench*.
(e) ISO 10380 - *Pipework - Corrugated metal hoses and hose assemblie*s.

Other standards may be accepted where agreed by LR.

13.4.3 All flexible hose assemblies are to be satisfactorily prototype burst tested to an international standard *see note* to demonstrate they are able to withstand a pressure of not less than four times the design pressure without indication of failure or leakage.

Note The international standards, e.g. EN or SAE for burst testing of non-metallic hoses, require the pressure to be increased until burst without any holding period at 4 x Maximum Working Pressure.

■ *Section 14*
Hydraulic tests on pipes and fittings

14.1 Hydraulic tests before installation on board

14.1.1 All Class I and II pipes and their associated fittings are to be tested by hydraulic pressure. Further, all steam, feed, compressed air and fuel oil pipes, together with their fittings, are to be similarly tested where the design pressure is greater than 7 bar. The test is to be carried out after completion of manufacture and before installation on board and, where applicable, before insulating and coating.

14.1.2 The test pressure is to be 1,5 times the design pressure, as defined in *Pt 15, Ch 1, 4.2 Design pressure*.

14.1.3 Shell valves and valves on the collision bulkhead are to be tested by hydraulic pressure to 1,5 times the nominal pressure rating of the valve at ambient temperature.

14.2 Testing after assembly on board

14.2.1 Fuel oil piping is to be tested by hydraulic pressure, after installation on board, to 1,5 times the design pressure but in no case to less than 3,5 bar.

14.2.2 Where pipes specified in *Pt 15, Ch 1, 14.1 Hydraulic tests before installation on board 14.1.1* are butt welded together during assembly on board, they are to be tested by hydraulic pressure in accordance with the requirements of *Pt 15, Ch 1, 14.2 Testing after assembly on board 14.2.1* after welding. The pipe lengths may be insulated, except in way of the joints made during installation and before the hydraulic test is carried out.

14.2.3 The hydraulic test required by *Pt 15, Ch 1, 14.2 Testing after assembly on board 14.2.2* may be omitted provided non destructive tests by ultrasonic or radiographic methods are carried out on the entire circumference of all butt welds with satisfactory results.

14.2.4 Where ultrasonic tests have been carried out, the manufacturer is to provide the Surveyor with a signed statement confirming that ultrasonic examination has been carried out by an approved operator and that there were no indications of defects which could be expected to have prejudicial effect on the service performance of the piping.

CROSS-REFERENCE

See also Pt 15, Ch 2, 2.5 Testing after installation for testing after installation.

■ *Section 15*
Requirements for small craft which are not required to comply with the HSC Code

15.1 General

15.1.1 The requirements of *Pt 15, Ch 1, 1 Application* to *Pt 15, Ch 1, 13 Flexible hoses* apply, except where modified by this Section.

15.2 Details to be submitted

15.2.1 Details of fuel oil storage tanks over 0,25 m^3, where these do not form part of the structure of the craft, are to be submitted.

15.2.2 Design details of the components listed in *Pt 15, Ch 1, 2.1 Plans and information 2.1.6* are not required.

15.3 Materials

15.3.1 Materials for which no provision is made in this Chapter may be accepted provided that they comply with an acceptable National or International Standard and are satisfactorily tested as may be considered necessary. Manufacturer's material test certificates are not required unless the material is of unusual or special specification.

15.3.2 Shell valves and cocks, inlet chests, distance pieces and other sea connections are to be of approved ductile material. Due attention is to be paid to the compatibility of the material with that of the shell. Ordinary grey cast iron is not acceptable.

15.4 Aluminium alloy

15.4.1 Proposals for the use of aluminium alloy pipes in bilge systems in machinery spaces will be considered, provided that a single failure in any section of the pipe does not render the whole system inoperable.

15.4.2 Aluminium alloy pipes may be used for fire-fighting systems outside machinery spaces in locations of low fire risk.

15.5 Plastic pipes

15.5.1 The requirements of *IMO Resolution A.753(18) - Guidelines for the Application of Plastic Pipes on Ships - (adopted on 4 November 1993)Amended by Resolution MSC.313(88)* and *Pt 15, Ch 1, 8.4 Fire performance criteria* do not apply.

15.5.2 The requirements of *Pt 15, Ch 1, 8.1 General 8.1.3* do not apply but where plastic pipes are used for bilge and cooling water services they are to be of a type which has been approved by LR. However, fire endurance testing is not required, *see Pt 15, Ch 1, 15.5 Plastic pipes 15.5.1*.

15.5.3 Where plastic pipes are used in bilge systems in machinery spaces, a single failure in any section of the pipe is not to render the whole system inoperable.

15.5.4 For other services where there are Rule requirements, plastic pipes are to be in accordance with an acceptable National or International Standard and suitable for the intended service conditions.

15.5.5 Plastic pipes are not to be used in machinery spaces and other spaces of high fire risk or on the open deck for conveying fuel oil, lubricating oil or other flammable liquids or for air and sounding pipes to tanks containing such liquids.

15.5.6 Plastic pipes used on the open deck for air and sounding pipes to other tanks are to be located in a sheltered position, protected from mechanical damage.

15.5.7 Plastic pipes used for overboard scuppers, sanitary discharges and seawater systems are to be provided with an approved ship-side valve. When the ship-side valve is arranged such that in any operating condition of the craft it is near or below the waterline, it is to be capable of being closed from a safe position above the bulkhead deck.

15.6 Copper and copper alloys

15.6.1 Where copper and copper alloy pipes are in accordance with an acceptable National Standard/Specification which is applicable to the intended service or media, *Table 1.6.1 Minimum thickness for copper and copper alloy pipes* need not be applied.

■ *Section 16*
Guidance notes on metal pipes for water services

16.1 General

16.1.1 These guidance notes, except where it is specifically stated, apply to sea-water piping systems.

16.1.2 In addition to the selection of suitable materials, careful attention should be given to the design details of the piping system and the workmanship in fabrication, construction and installation of the pipework in order to obtain maximum life in service.

16.2 Materials

16.2.1 Materials used in sea water piping systems include:

- Galvanised steel.
- Stainless and duplex steel, *see also Pt 15, Ch 1, 16.3 Steel pipes 16.3.4*.
- Steel pipes lined with rubber, plastics or stoved coatings.
- Copper.
- 90/10 copper-nickel-iron.
- 70/30 copper-nickel.
- Aluminium alloy.
- Aluminium brass.
- Bronze.
- Approved plastics.

16.2.2 Selection of materials should be based on:

- The ability to resist general and localized corrosion, such as pitting, impingement attack and cavitation throughout all the flow velocities likely to be encountered;
- Compatibility with the other materials in the system, such as valve bodies and casings, in order to minimise bimetallic corrosion;
- The ability to resist selective corrosion, e.g. dezincification of brass, dealuminification of aluminium brass and graphitisation of cast iron;

- The ability to resist stress corrosion and corrosion fatigue, and;
- The amenability to fabrication by normal practices.

16.3 Steel pipes

16.3.1 Steel pipes should be protected against corrosion and protective coatings should be applied on completion of all fabrication, i.e. bending, forming and welding of the steel pipes.

16.3.2 Welds should be free from lack of fusion and crevices. The surfaces should be dressed to remove slag and spatter and this should be done before coating. The coating should be continuous around the ends of the pipes and on the faces of flanges.

16.3.3 Galvanising the bores and flanges of steel pipes as protection against corrosion is common practice, and is recommended as the minimum protection for pipes in sea-water systems, including those for bilge and ballast service.

16.3.4 Austenitic and duplex stainless steel pipes are not recommended for salt water services in polluted waters or where stagnant conditions exist. Austenitic stainless steel pipes grades 316L or 317L and duplex stainless steels grades S31803 or S32750 may give satisfactory service in water circulating systems for clean flowing sea water.

16.3.5 Rubber lined pipes are effective against corrosion and suitable for higher water velocities. The rubber lining should be free from defects, e.g. discontinuities, pinholes, etc. and it is essential that the bonding of the rubber to the bore of the pipe and flange face is sound. Rubber linings should be applied by firms specialising in this form of protection.

16.3.6 The foregoing comments on rubber lined pipes also apply to pipes lined with plastics.

16.3.7 Stove coating of pipes as protection against corrosion should only be used where the pipes will be efficiently protected against mechanical damage.

16.4 Copper and copper alloy pipes

16.4.1 Copper pipes are particularly susceptible to perforation by corrosion/erosion and should only be used for low water velocities and where there is no excessive local turbulence.

16.4.2 Aluminium brass and copper-nickel-iron alloy pipes give good service in reasonably clean sea-water. For service with polluted river or harbour waters, copper-nickel-iron alloy pipes with at least 10 per cent nickel are preferable. Alpha-brasses, i.e. those containing 70 per cent or more copper, must be inhibited effectively against dezincification by suitable additions to the composition. Alpha beta-brasses, i.e. those containing less than 70 per cent copper, should not be used for pipes and fittings.

16.4.3 New copper alloy pipes should not be exposed initially to polluted water. Clean sea-water should be used at first to allow the metals to develop protective films. If this is not available the system should be filled with inhibited town mains water.

16.5 Flanges

16.5.1 Where pipes are exposed to sea-water on both external and internal surfaces, flanges should be made, preferably, of the same material. Where sea-water is confined to the bores of pipes, flanges may be of the same material or of less noble metal than that of the pipe.

16.5.2 Fixed or loose type flanges may be used. The fixed flanges should be attached to the pipes by fillet welds or by capillary silver brazing. Where welding is used, the fillet weld at the back should be a strength weld and that in the face, a seal weld.

16.5.3 Inert gas shielded arc welding is the preferred process but metal arc welding may be used on copper-nickel-iron alloy pipes.

16.5.4 Mild steel flanges may be attached by argon arc welding to copper-nickel-iron pipes and give satisfactory service, provided that no part of the steel is exposed to the sea-water.

16.5.5 Where silver brazing is used, strength should be obtained by means of the bond in a capillary space over the whole area of the mating surfaces. A fillet braze at the back of the flange or at the face is undesirable. The alloy used for silver brazing should contain not less than 49 per cent silver.

16.5.6 The use of a copper-zinc brazing alloy is not permitted.

16.6 Water velocity

16.6.1 Water velocities should be carefully assessed at the design stage and the materials of pipes, valves, etc. selected to suit the conditions.

16.6.2 The water velocity in copper pipes should not exceed 1 m/s.

16.6.3 The water velocity in the pipes of the materials below should normally be not less than about 1 m/s in order to avoid fouling and subsequent pitting, but should not be greater than the following:

Galvanised steel	3,0 m/s
Aluminium brass	3,0 m/s
90/10 copper-nickel-iron	3,5 m/s
70/30 copper-nickel	5,0 m/s.

16.7 Fabrication and installation

16.7.1 Attention should be given to ensuring streamlined flow and reducing entrained air in the system to a minimum. Abrupt changes in the direction of flow, protrusions in the bores of pipes and other restrictions of flow should be avoided. Branches in continuous flow lines should be set at a shallow angle to the main pipe, and the junction should be smooth.

16.7.2 Pipe bores should be smooth and clean.

16.7.3 Jointing should be flush with the bore surfaces of pipes and misalignment of adjacent flange faces should be reduced to a minimum.

16.7.4 Pipe bends should be of as large a radius as possible, and the bore surfaces should be smooth and free from puckering at these positions. Any carbonaceous films or deposits formed on the bore surfaces during the bending processes should be carefully removed. Organic substances are not recommended for the filling of pipes for bending purposes.

16.7.5 The position of supports should be given special consideration in order to minimise vibration and ensure that excessive bending moments are not imposed on the pipes.

16.7.6 Systems should not be left idle for long periods, especially where the water is polluted.

16.7.7 Strainers should be provided at the inlet to sea-water systems.

16.8 Metal pipes for fresh water services

16.8.1 Mild steel or copper pipes are normally satisfactory for service in fresh water applications. Hot fresh water, however, may promote corrosion in mild steel pipes unless the hardness and pH of the water are controlled.

16.8.2 Water with a slight salt content should not be left stagnant for long periods in mild steel pipes. Low salinity and the limited supply of oxygen in such conditions promote the formation of black iron oxide, and this may give rise to severe pitting. Where stagnant conditions are unavoidable, steel pipes should be galvanised, or pipes of suitable non-ferrous material used.

16.8.3 Copper alloy pipes should be treated to remove any carbonaceous films or deposits before the tubes are put into service.

16.8.4 Brass fittings and flanges in contact with water should be made of an alpha-brass effectively inhibited against dezincification by suitable additions to the composition.

16.8.5 Aluminium brass has been widely used as material for heat exchanger and condenser tubes, but its use in `once through' systems is not recommended since, under certain conditions, it is prone to pitting and cracking.

■ *Section 1* **General**

1.1 Application

1.1.1 The requirements of *Pt 15, Ch 2, 1 General* to *Pt 15, Ch 2, 12 Additional requirements relating to fixed pressure water spray fire-extinguishing systems*of this Chapter apply to all craft which are required to satisfy the relevant design and construction regulations of the HSC Code.

1.1.2 Additional requirements for Passenger (B) Craft are given in *Pt 15, Ch 2, 13 Additional requirements for Passenger (B) Craft*.

1.1.3 Requirements for craft of less than 24 m not required to comply with the HSC Code are given in *Pt 15, Ch 2, 14 Requirements for small craft which are not required to comply with the HSC Code*.

1.1.4 Requirements for yachts and service craft of 24 m or more not required to comply with the HSC Code are given in *Pt 15, Ch 2, 15 Requirements for yachts and service craft of 24 m or greater in length, which are not required to comply with the HSC Code*. The requirements for yachts satisfy the relevant requirements of the UK MCA LY3 Code.

1.1.5 The requirements for air cushion vehicles are given in *Pt 15, Ch 2, 16 Requirements for Air Cushion Vehicles*.

1.1.6 Special consideration shall be given to passenger craft not required to comply with the HSC Code.

1.1.7 In addition to the requirements of this Chapter, attention should be given to any relevant statutory requirements of the National Authority of the country in which the craft is to be registered.

1.1.8 Consideration will be given to special cases or to arrangements which are equivalent to those required by these Rules.

1.2 Details to be submitted

1.2.1 The plans and information detailed in *Pt 15, Ch 1 Piping Design Requirements* are to be submitted before commencement of work.

1.3 Watertight and non-watertight decks

1.3.1 For the purpose of this Section, a non-watertight deck covered by a weathertight structure may be taken as equivalent to a watertight deck. For definitions of the terms watertight and weathertight, *see Pt 3, Ch 1 General Regulations*.

1.4 Prevention of progressive flooding in damage condition

1.4.1 For craft to which subdivision and damage stability requirements apply, precautions are to be taken to prevent progressive flooding between compartments resulting from damage to piping systems. For this purpose, piping systems are to be located inboard of the assumed extent of damage applicable to the craft type.

1.4.2 Where it is not practicable to locate piping systems as required by *Pt 15, Ch 2, 1.4 Prevention of progressive flooding in damage condition 1.4.1*, the following precautions are to be taken:

(a) Bilge suction pipes are to be provided with non-return valves of approved type.

(b) Other piping systems are to be provided with shut-off valves capable of being operated from positions accessible in the damage condition, or from above the bulkhead deck where required by the Rules.

These valves are to be located in the compartment containing the open end or in a suitable position such that the compartment may be isolated in the event of damage to the piping system.

1.4.3 Where subdivision and damage stability requirements apply and where penetration of watertight divisions by pipes, ducts, trunks or other penetrations is necessary, arrangements are to be made to maintain the watertight integrity.

■ *Section 2*
Construction and installation

2.1 Installation

2.1.1 All pipes for essential services are to be secured in position to prevent chafing or lateral movement.

2.1.2 Long or heavy lengths of pipe are to be supported by bearers so that no undue load is carried by pipe connections or pumps and fittings to which they are attached.

2.2 Provision for expansion

2.2.1 Suitable provision for expansion is to be made, where necessary, in each range of pipes.

2.2.2 Where expansion pieces are fitted, arrangements are to be provided to protect against over extension and compression. The adjoining pipes are to be suitably aligned, supported, guided and anchored. Where necessary, expansion pieces of the bellows type are to be protected against mechanical damage.

2.2.3 Expansion pieces of an approved type incorporating oil resistant rubber or other suitable synthetic material may be used in cooling water lines in machinery spaces. Where fitted in sea-water lines, they are to be provided with guards which will effectively enclose, but not interfere with, the action of the expansion pieces and will reduce to the minimum practicable any flow of water into the machinery spaces in the event of failure of the flexible elements. Where the provision of such guards is not practicable, consideration will be given to alternative arrangements which provide an equivalent level of protection. Proposals to use such fittings in water lines for other services, including:

- ballast lines in machinery spaces, in duct keels and inside double bottom water ballast tanks, and
- bilge lines inside duct keels only,

will be specially considered when plans of the pumping systems are submitted for approval.

2.2.4 For requirements relating to flexible hoses, *see Pt 15, Ch 1 Piping Design Requirements*.

2.3 Attachment of valves to watertight plating

2.3.1 Valve chests, cocks, pipes or other fittings attached direct to the plating of tanks, and to bulkheads, flats or tunnels which are required to be of watertight construction, are to be secured by means of studs or tap bolts screwed through bulkhead pieces welded to the plating, and not by bolts passing through clearance holes. For tanks, the stud or tap bolt holes are not to penetrate the plating.

2.3.2 For composite hulls, *see Pt 15, Ch 2, 14.4 Fittings for composite hulls 14.4.5*.

2.4 Miscellaneous requirements

2.4.1 All pipes situated in cargo spaces, chain lockers or other positions where they are liable to mechanical damage are to be efficiently protected.

2.4.2 So far as practicable, pipelines, including exhaust pipes from engines, are not to be routed in the vicinity of switchboards or other electrical appliances in positions where the drip or escape of fluids, gas or steam from joints or fittings could cause damage to the electrical installation. Where it is not practicable to comply with these requirements, drip trays or shields are to be provided as found necessary.

2.5 Testing after installation

2.5.1 After installation on board, all steam, hydraulic, compressed air and other piping systems covered by *Pt 15, Ch 1, 2.1 Plans and information* together with associated fittings which are under internal pressure, are to be subjected to a running test at the intended maximum working pressure.

■ *Section 3*
Shell valves and fittings (other than those on scuppers and sanitary discharges)

3.1 Construction

3.1.1 All sea inlet and overboard discharge pipes are to be fitted with valves or cocks secured direct to the shell plating, or to fabricated water boxes attached to the shell plating. These fittings are to be secured by studs or by tap bolts screwed into heavy pads welded to the plating. The stud or tap bolt holes are not to penetrate the plating.

3.1.2 Alternatively, distance pieces of short rigid construction and made of approved material may be fitted between the valves and the shell plating. The thickness of such pipes is to be equivalent to shell thickness. Distance pieces of steel may be welded to steel shell plating and distance pieces of aluminium alloy may be welded to aluminium alloy shell plating. Details of the welded connections and of fabricated boxes are to be submitted.

3.1.3 The arrangements are to be such that the section of pipe immediately inboard of the shell valve may be removed without affecting the watertight integrity of the hull.

3.1.4 The valves are to be in accordance with the general requirements for valves given in *Pt 15, Ch 1, 12 Requirements for valves*.

3.1.5 Shell valves are to be manufactured from non-heat sensitive materials and tested in accordance with the appropriate requirements of the *Rules for the Manufacture, Testing and Certification of Materials, July 2021* (hereinafter referred to as the Rules for Materials). Special consideration will be given to the use of other materials on craft of aluminium or composite construction. Where the valves are manufactured from spheroidal or nodular graphite cast iron they are to be produced at a works approved by Lloyd's Register (hereinafter referred to as 'LR'). Grey cast iron is not acceptable.

3.1.6 Shell valves are to be fitted in accessible positions and are to be capable of being operated from positions which are readily accessible in case of influx of water to the compartment.

3.1.7 Valve hand wheels and cock handles are to be suitably retained on the spindles. Means are to be provided to indicate whether the valve or cock is open or closed.

3.1.8 The scantlings of valves and valve stools fitted with steam or compressed air clearing connections are to be suitable for the maximum pressure to which the valves and stools may be subjected.

3.1.9 Shell valves are to be hydraulically tested before installation in accordance with *Pt 15, Ch 1, 14 Hydraulic tests on pipes and fittings*.

3.1.10 For sea connections for craft having notation for ice navigation, *see* LR's *Rules and Regulations for the Classification of Ships*, *Pt 8, Ch 2, 3.3 Laminating*, *Pt 8, Ch 2, 3.5 Laminate schedule* and *Pt 8, Ch 2, 5.6 Through hull fittings*.

3.2 Special requirements for composite hulls

3.2.1 The general requirements in *Pt 15, Ch 2, 3.1 Construction* apply, however the valves or cocks are to be secured to the shell plating as detailed in *Pt 15, Ch 2, 14.4 Fittings for composite hulls*.

■ *Section 4* Bilge pumping and drainage systems

4.1 General

4.1.1 Arrangements are to be made for draining all watertight compartments other than those intended for permanent storage of fluids. Where drainage is not considered necessary, drainage arrangements may be omitted provided the safety of the craft is not impaired.

4.1.2 Pumping arrangements are to be provided having suctions and means of drainage so arranged that any water within any watertight compartment of the craft or any watertight section of any compartment, can be pumped out through at least one suction under all possible conditions of list and trim in the maximum assumed damage condition.

4.1.3 The bilge pumping system is to be designed to prevent water flowing from one watertight compartment to another.

4.1.4 The necessary valves for controlling the bilge suctions are to be capable of being operated from above the watertight deck.

4.1.5 Where a bilge main is not fitted and a compartment is served by a fixed submersible pump in accordance with *Pt 15, Ch 2, 10 Submersible bilge pump arrangements*, then an additional emergency means of pumping out the compartment is to be provided, *see Pt 15, Ch 2, 6 Emergency bilge drainage*.

4.1.6 Small compartments may be drained by individual hand pump suctions.

4.1.7 The intactness of watertight bulkheads is not to be impaired by the fitting of scuppers discharging to machinery spaces or tunnels from adjacent compartments situated below the highest watertight deck.

4.1.8 Any unattended space for which bilge pumping arrangements are required is to be provided with a bilge level alarm.

4.1.9 Where it is intended to carry flammable or toxic liquids in enclosed spaces, the bilge system shall be designed to prevent pumping of such liquids through piping and pumps in machinery or other spaces where a source of ignition may exist.

4.2 Drainage of raft void spaces on multi-hull craft

4.2.1 Where the raft void space is located above the water line in the maximum assumed damage condition, then it may be drained directly overboard through scuppers fitted with non-return valves of approved type.

4.2.2 Raft void spaces which are not located above the water line in the maximum assumed damage condition are to be provided with pumping arrangements in accordance with *Pt 15, Ch 2, 4.1 General*.

■ *Section 5* Bilge drainage of machinery spaces with a propulsion prime mover

5.1 General

5.1.1 The bilge drainage arrangements are to comply with *Pt 15, Ch 2, 4 Bilge pumping and drainage systems*, except that the arrangements are to be such that any water which may enter this compartment can be pumped out through at least two bilge suctions under all possible conditions of list and trim in the maximum assumed damage condition.

5.1.2 Where a bilge main is fitted, one of the suctions referred to in *Pt 15, Ch 2, 5.1 General 5.1.1* is to be a branch bilge suction i.e. a suction connected to the bilge main. The second bilge suction is to be a direct bilge suction as detailed in *Pt 15, Ch 2, 8.6 Direct bilge suctions*.

5.1.3 Where a bilge main is not fitted, the branch bilge suction referred to in *Pt 15, Ch 2, 5.1 General 5.1.2* may be replaced by a suction from a submersible bilge pump. The second bilge suction is to be either a second submersible bilge pump or a direct bilge suction as detailed in *Pt 15, Ch 2, 8.6 Direct bilge suctions*.

5.1.4 The emergency bilge drainage arrangements detailed in *Pt 15, Ch 2, 6 Emergency bilge drainage* are to be provided where either *Pt 15, Ch 2, 5.1 General 5.1.2* or *Pt 15, Ch 2, 5.1 General 5.1.3* applies.

5.2 Additional bilge suctions

5.2.1 Additional bilge suctions may be required for the drainage of wells or other recesses.

■ *Section 6*
Emergency bilge drainage

6.1 Emergency bilge drainage

6.1.1 In machinery spaces the emergency bilge suction required by *Pt 15, Ch 2, 4.1 General 4.1.5* and *Pt 15, Ch 2, 5.1 General 5.1.4* is to be led to the largest available power pump, which is not a bilge, propulsion or oil pump, from a suitable low level in the machinery space and is to be fitted with a screw-down non-return valve with an extended spindle and hand wheel situated above the floor plating.

6.1.2 As an alternative to *Pt 15, Ch 2, 6.1 Emergency bilge drainage 6.1.1*, or in compartments other than machinery spaces, the emergency bilge pumping arrangements may be provided by a portable submersible self-priming pump of capacity not less than that required by *Pt 15, Ch 2, 8.3 Capacity of pumps 8.3.5*.

6.1.3 The pump referred to in *Pt 15, Ch 2, 6.1 Emergency bilge drainage 6.1.2* together with its suction and delivery hoses is to be stored in a locker marked `For emergency use only' and is to be available for immediate use. Arrangements to facilitate safe handling under adverse conditions are to be provided. If the pump is electrically driven it is to be supplied from the emergency switchboard.

6.1.4 Where **UMS** (Unattended Machinery Space) notation is to be assigned, the requirements of *Pt 16, Ch 1, 4.7 Bilge level detection 4.7.2* are not applicable for valves serving an emergency bilge system, provided that:

(a) the emergency bilge valve is normally maintained in a closed position;
(b) a non-return device is installed in the emergency bilge piping; and
(c) the emergency bilge suction piping is located inboard of a shell valve that is fitted with the control arrangements complying with *Pt 16, Ch 1, 4.7 Bilge level detection 4.7.2*.

■ *Section 7*
Size of bilge suction pipes

7.1 Bilge main

7.1.1 Where a bilge main is fitted, its internal diameter d_m is to be not less than that required by the following formula:

$$d_m = 1,68\sqrt{L(B+D)} + 25 \text{ mm}$$

where

B = breadth of craft, in metres, for mono-hull craft

= breadth of a single hull in metres, for multi-hull craft

D = moulded depth to the watertight deck, in metres

where

L = length of craft, in metres.

The actual internal diameter of the bilge main may be rounded off to the nearest pipe size of a recognised standard, but d_m is in no case to be less than 50 mm.

7.2 Branch bilge suctions

7.2.1 The diameter d_b of branch bilge suction pipes is to be not less than that required by the following formula:

$$d_b = 2,15\sqrt{C(B+D)} + 12,5 \text{ mm}$$

where

B and D = are as defined in *Pt 15, Ch 2, 7.1 Bilge main 7.1.1*

C = length of compartment, in metres.

The actual internal diameter of branch bilge suction pipes may be rounded off to the nearest pipe size of a recognised standard, but d_b is in no case to be less than 25 mm.

■ *Section 8*
Pumps on bilge service

8.1 Number of pumps

8.1.1 For craft fitted with a bilge main, at least two power bilge pumping units are to be provided. One of these units may be worked from the main engines and the other is to be independently driven.

8.1.2 For multi-hull craft, the power bilge pumping units in *Pt 15, Ch 2, 8.1 Number of pumps 8.1.1* are to take suction from the bilge main in each hull. Where the bilge system in each hull is entirely separate, at least two power bilge pumping units are to be provided in each hull.

8.1.3 Each unit may consist of one or more pumps connected to the main bilge line, provided that their combined capacity is not less than that required by *Pt 15, Ch 2, 8.3 Capacity of pumps 8.3.2*.

8.1.4 A bilge ejector in combination with a high pressure sea-water pump may be accepted as a substitute for an independent bilge pump as required by *Pt 15, Ch 2, 8.1 Number of pumps 8.1.1*.

8.1.5 For craft fitted with fixed submersible bilge pumps, one pump is to be provided for each watertight compartment.

8.2 General service pumps

8.2.1 The bilge pumping units or pumps required by *Pt 15, Ch 2, 8.1 Number of pumps* may also be used for ballast, fire or general service duties of an intermittent nature, but not for pumping fuel or other flammable liquids. These pumps are to be immediately available for bilge duty when required.

8.3 Capacity of pumps

8.3.1 Each bilge pumping unit is to be connected to the bilge main and is to be capable of giving a speed of water through the Rule size of bilge main of not less than 2 m/s.

8.3.2 To achieve the flow velocity required by *Pt 15, Ch 2, 8.3 Capacity of pumps 8.3.1*, the capacity Q of each bilge pumping unit or bilge pump is to be not less than that required by the following formula:

$$Q = \frac{5,75}{10^3} d_m^2 \quad \text{m}^3/\text{hour}$$

where

d_m = is as defined in *Pt 15, Ch 2, 7.1 Bilge main 7.1.1*.

where

Q = Rule minimum capacity, in m^3/hour

8.3.3 Where one bilge pumping unit is of slightly less than Rule capacity, the deficiency may be made good by an excess capacity of the other unit. In general, the deficiency is to be limited to 30 per cent.

8.3.4 Where fixed submersible bilge pumps are fitted, the total capacity Q_t of the pumps (in each hull for multi-hull craft) is to be not less than that required by the following formula:

$$Q_t = \frac{13,8}{10^3} d_m^2 \text{ m}^3\text{/hour}$$

where

d_m = is as defined in *Pt 15, Ch 2, 7.1 Bilge main 7.1.1*.

Q_t = Rule minimum total capacity, in m^3/hour

8.3.5 The capacity Q_n of each submersible bilge pump is to be not less than that required by the following formula:

$$Q_n = \frac{Q_t}{(N-1)} \text{ m}^3\text{/hour}$$

where

N = number of fixed submersible pumps (in each hull for multi-hull craft)

Q_t = is as defined in *Pt 15, Ch 2, 8.3 Capacity of pumps 8.3.4*

Q_n = Rule minimum submersible pump capacity, in m^3/hour

Q_n = is in no case to be less than 8 m^3/hour.

8.4 Self-priming pumps

8.4.1 All power pumps which are essential for bilge services are to be of the self-priming type, unless an approved central priming system is provided for these pumps.

8.5 Pump connections

8.5.1 The connections at the bilge pumps are to be such that one unit may continue in operation when the other unit is being opened up for overhaul.

8.5.2 Pumps required for essential services are not to be connected to a common suction or discharge chest or pipe unless the arrangements are such that the working of any pumps so connected is unaffected by the other pumps being in operation at the same time.

8.6 Direct bilge suctions

8.6.1 The direct bilge suction in the machinery space required by *Pt 15, Ch 2, 5.1 General 5.1.2* and referred to in *Pt 15, Ch 2, 5.1 General 5.1.3* is to be led to an independent power pump, and the arrangements are to be such that the direct suction can be used independently of the main bilge line suctions.

8.6.2 The machinery space direct bilge suction is not to be of a diameter less than that required for the machinery space branch bilge suction and arranged as detailed in *Pt 15, Ch 2, 8.6 Direct bilge suctions 8.6.1*.

Section 9
Bilge main arrangements and materials

9.1 General

9.1.1 Bilge mains, branch bilge suctions and bilge overboard discharge arrangements within machinery spaces are to be of steel or other equivalent material.

9.1.2 Where bilge suction pipework outside machinery spaces is manufactured from material sensitive to heat then the arrangements are to be such that pipe failure in one compartment will not render the bilge suction pipework in another compartment inoperable.

9.1.3 Bilge pipework is to be mounted inboard such that in the event of the maximum assumed damage the pipework will remain intact.

9.2 Prevention of communication between compartments

9.2.1 The arrangement of valves, cocks and their connections is to be such as to prevent the possibility of one watertight compartment being placed in communication with another, or of dry cargo spaces, machinery spaces or other dry compartments being placed in communication with the sea or with tanks. For this purpose, screw-down non-return valves are to be provided in the following fittings:

- Bilge valve distribution chests.
- Bilge suction hose connections, whether fitted direct to the pump or on the main bilge line.
- Direct bilge suctions and bilge pump connections to the main bilge line.

9.3 Isolation of bilge system

9.3.1 Bilge suction pipes are to be entirely separate from sea inlet pipes or from pipes which may be used for filling or emptying spaces where water or oil is carried.

9.4 Bilge suction strainers

9.4.1 The open ends of bilge suctions are to be enclosed in strum boxes having perforations of not more than 10 mm diameter, whose combined area is not less than twice that required for the suction pipe. The boxes are to be so constructed that they can be cleared without breaking any joint of the suction pipe.

Section 10
Submersible bilge pump arrangements

10.1 General

10.1.1 Arrangements are to be such that at least two automatic non-return devices are fitted between the overboard discharge and the watertight space being served by the pump.

10.1.2 One of these devices is to be an automatic non-return valve situated at or near the shell and the other may be a pipework loop taken up to the highest practicable point below the watertight deck. The arrangements are to be effective in the maximum assumed damaged condition.

10.1.3 The suction of the pump is to be fitted with a suitable strainer which can be easily removed for cleaning.

Section 11
Air, overflow and sounding pipes

11.1 Air pipes

11.1.1 Air pipes are to be fitted to all tanks, cofferdams, tunnels and other compartments which are not fitted with alternative ventilation arrangements.

11.1.2 Air pipes are to be fitted at the opposite end of the tank to that which the filling pipes are placed and/or at the highest part of the tank. Where the tank top is of unusual or irregular profile, special consideration will be given to the number and position of the air pipes.

11.1.3 Air pipes are to be made of steel or other approved material. For use of aluminium alloy and plastic pipes of approved type, *see Pt 15, Ch 1 Piping Design Requirements*.

11.1.4 Air pipes to fuel oil tanks serving emergency generators may not be led through Category 'A' machinery spaces.

11.1.5 For a normally inaccessible small void compartment such as an echo sounding compartment, which is accessed from within a normally inaccessible space such as a forepeak tank, alternative air pipe arrangements to those required by 11.1.1 may be considered. For such arrangements, a warning notice is to be located in a prominent position specifying the precautions to be taken prior to opening the manhole and entering the small void compartment. Ventilation arrangements are to be submitted to LR for approval.

11.2 Termination of air pipes

11.2.1 Air pipes to double bottom tanks, deep tanks extending to the shell plating, or tanks which can be run up from the sea are to be led to above the watertight deck. Air pipes to fuel oil tanks, cofferdams and all tanks which can be pumped up are to be led to the open.

11.2.2 Air pipes from storage tanks containing lubricating or hydraulic oil may terminate in the machinery space, provided that the open ends are so situated that issuing oil cannot come into contact with electrical equipment or heated surfaces.

11.2.3 The open ends of air pipes to fuel oil tanks are to be situated where no danger will be incurred from issuing oil vapour when the tank is being filled.

11.2.4 The location and arrangement of air pipes for fuel oil service, settling and lubricating oil tanks are to be such that in the event of a broken vent pipe, this does not directly lead to the risk of ingress of sea-water or rainwater.

11.3 Gauze diaphragms

11.3.1 The open ends of air pipes to fuel oil tanks are to be fitted with a wire gauze diaphragm of non-corrodible material which can be readily removed for cleaning or renewal.

11.3.2 Where wire gauze diaphragms are fitted at air pipe openings, the area of the opening through the gauze is to be not less than the cross-sectional area required for the pipe, *see Pt 15, Ch 2, 11.6 Size of air pipes*.

11.4 Air pipe closing appliances

11.4.1 The closing appliances fitted to tank air pipes, in accordance with *Pt 3, Ch 4, 12 Air and sounding pipes*, are to be of an automatic opening type which will allow the free passage of air or liquid to prevent the tanks being subjected to a pressure or vacuum greater than that for which they are designed, and prevent the free entry of water into the tanks.

11.4.2 Air pipe closing devices are to be type tested in accordance with the test requirements of LR's Type Approval Test Specification Number 2. The flow characteristic of the closing device is to be determined using water, *see Pt 15, Ch 2, 11.6 Size of air pipes 11.6.1* and *Pt 15, Ch 2, 11.6 Size of air pipes 11.6.2*.

11.4.3 Wood plugs and other devices which can be secured closed are not to be fitted at the outlets.

11.4.4 Air pipe automatic closing devices shall be so designed that they will withstand both ambient conditions as indicated in *Pt 9, Ch 1, 4.4 Ambient reference conditions* and *Pt 9, Ch 1, 4.5 Ambient operating conditions* and designed working conditions, and be suitable for use at inclinations up to and including ± 40°.

11.4.5 Air pipe automatic closing devices shall be constructed to allow inspection of the closure and the inside of the casing, as well as changing the seals.

11.4.6 Efficient ball or float seating arrangements are to be provided for the closures. Bars, cages or other devices are to be provided to prevent the ball or float from contacting the inner chamber in its normal state, and made in such a way that the ball or float is not damaged when subjected to liquid impact due to a tank being overfilled.

11.4.7 Air pipe automatic closing devices are to be self-draining.

11.4.8 The clear area through an air pipe closing device in the open position shall be at least equal to the area of the inlet.

11.4.9 In the case of air pipe closing devices of the float type, suitable guides are to be provided to ensure unobstructed operation under all working conditions of heel and trim as specified in *Pt 15, Ch 2, 11.4 Air pipe closing appliances 11.4.4*.

11.4.10 The maximum allowable tolerances for wall thickness of floats should not exceed ±10 per cent of thickness.

11.4.11 The inner and the outer chambers of an automatic air pipe head are to be of a minimum thickness of 6 mm. Where side covers are provided, and their function is integral to providing functions of the closing device as outlined in*Pt 15, Ch 2, 11.4 Air pipe closing appliances 11.4.1*, they shall have a minimum wall thickness of 6 mm. If the air pipe head can meet the tightness test in LR's Type Approval Test Specification Number 2 without the side covers attached, then the side covers are not considered to be integral to the closing device, in which case a wall thickness less than 6 mm will be accepted.

11.4.12 Casings of air pipe closing devices are to be of approved metallic materials adequately protected against corrosion.

11.4.13 For galvanised steel air pipe heads, the zinc coating is to be applied by the hot method and the thickness is to be 70 to 100 microns.

11.4.14 For areas of the head susceptible to erosion (e.g. those parts directly subjected to ballast water impact when the tank is being pressed up, for example the inner chamber area above the air pipe, plus an overlap of 10° or more either side) an additional harder coating should be applied. This is to be an aluminium bearing epoxy, or other equivalent coating, applied over the zinc.

11.4.15 Closures and seats made of non-metallic materials are to be compatible with the media intended to be carried in the tank and with sea-water, and suitable for operating at ambient temperatures between –25°C and 85°C.

11.5 Nameplates

11.5.1 Nameplates are to be affixed to the upper ends of all air and sounding pipes.

11.6 Size of air pipes

11.6.1 For every tank which can be filled by on-board pumps, the total cross-sectional area of the air pipes and the air pipe closing devices is to be such that when the tank is overflowing at the maximum pumping capacity available for the tank, it will not be subjected to a pressure greater than that for which it is designed.

11.6.2 In all cases, whether a tank is filled by on-board pumps or other means, the total cross-sectional area of the pipes is to be not less than 25 per cent greater than the effective area of the respective filling pipe.

11.6.3 Air pipes are to be generally not less than 38 mm bore. In the case of small gravity filled tanks smaller bore pipes may be accepted but in no case is the bore to be less than 25 mm.

11.7 Overflow pipes

11.7.1 For all tanks which can be pumped up, overflow pipes are to be fitted where:

(a) The total cross-sectional area of the air pipes is less than that required by *Pt 15, Ch 2, 11.6 Size of air pipes*.
(b) The pressure head corresponding to the height of the air pipe is greater than that for which the tank is designed.

11.7.2 In the case of fuel oil tanks, lubricating oil tanks and other tanks containing flammable liquids, the overflow pipe is to be led to an overflow tank of adequate capacity or to a storage tank having a space reserved for overflow purposes. Suitable means is to be provided to indicate when overflowing is occurring.

11.7.3 Overflow pipes are to be self draining under normal conditions of trim.

11.7.4 Where overflow sight glasses are provided, they are to be in a vertical dropping line and designed such that the oil does not impinge on the glass. The glass is to be of heat resisting quality and be adequately protected from mechanical damage. Overflow sight glasses are not permitted in fuel oil systems for craft required to comply with the HSC Code.

11.8 Combined air and overflow systems

11.8.1 Where a combined air or overflow system is fitted, the arrangement is to be such that in the event of any one of the tanks being bilged, the other tanks cannot be flooded from the sea through combined air pipes or the overflow main. For this purpose, it will normally be necessary to lead the overflow pipe to a point above the waterline in the maximum assumed damage condition.

11.8.2 Where tanks vent via a common tank, such as an overflow tank, extending to the shell plating, flooding of this tank as a result of damage to the shell plating is not to render the entire venting system inoperable.

11.8.3 Where a common overflow main is provided, the main is to be sized to allow any two tanks connected to that main to overflow simultaneously.

11.9 Sounding arrangements

11.9.1 Provision is to be made for sounding all tanks and the bilges of those compartments which are not at all times readily accessible. The soundings are to be taken as near the suction pipes as practicable.

11.9.2 Sounding devices of an approved type (i.e. level gauge or remote reading level device) may be used in lieu of sounding pipes.

11.9.3 Bilges of compartments which are not at all times readily accessible are to be provided with sounding pipes.

11.9.4 Where fitted, sounding pipes are to be as straight as practicable, and if curved to suit the structure of the craft, the curvature is to be sufficiently easy to permit the ready passage of the sounding rod or chain.

11.9.5 Striking plates of adequate thickness and size are to be fitted under open ended sounding pipes.

11.9.6 Where slotted sounding pipes having closed ends are employed, the closing plugs are to be of substantial construction.

11.9.7 Sounding pipes are to be not less than 32 mm bore.

11.9.8 For a normally inaccessible small void compartment such as an echo sounding compartment, which is accessed from within a normally inaccessible space such as a forepeak tank, alternative sounding arrangements to those required by *Pt 15, Ch 2, 11.9 Sounding arrangements 11.9.1* may be considered. For such arrangements, a warning notice is to be located in a prominent position specifying precautions to be taken prior opening the manhole of the small void compartment. Means are to be provided to indicate flooding of the compartment without opening, such as fitting indicator plugs to the manhole. Sounding arrangements are to be submitted to LR for approval.

11.9.9 Sounding pipes are to be made of steel or other approved material. For use of aluminium alloy and plastic pipes of approved type, *see Pt 15, Ch 1 Piping Design Requirements*.

11.10 Termination of sounding pipes

11.10.1 Except as permitted by *Pt 15, Ch 2, 11.11 Short sounding pipes*, sounding pipes are to be led to positions above the bulkhead deck which are at all times accessible and, in the case of fuel oil tanks, cargo oil tanks and lubricating oil tanks, the sounding pipes are to be led to safe positions on the open deck.

11.10.2 For closing requirements, *see also Pt 3, Ch 4, 12.3 Closing appliances 12.3.1*.

11.11 Short sounding pipes

11.11.1 In machinery spaces, where it is not practicable to extend sounding pipes, as mentioned in *Pt 15, Ch 2, 11.10 Termination of sounding pipes*, short sounding pipes extending to readily accessible positions above the platform may be fitted.

11.11.2 Short sounding pipes are not permitted in machinery spaces for tanks containing fuel oil or other flammable oils used in power transmission systems, control and activating systems and heating systems, except as permitted by *Pt 15, Ch 2, 11.13 Sounding arrangements for fuel oil, lubricating oil and other flammable liquids 11.13.6*.

11.11.3 Short sounding pipes may be fitted to tanks used for the storage, distribution and utilisation of lubricating oil in machinery spaces. These sounding pipes are to be fitted with cocks having parallel plugs with permanently attached handles, located such that, on being released, they automatically close the cocks.

11.12 Elbow sounding pipes

11.12.1 In passenger craft, elbow sounding pipes are not permitted.

11.12.2 Elbow sounding pipes are not to be used for deep tanks, unless the elbows and pipes are situated within closed cofferdams or within tanks containing similar liquids. They may, however, be fitted to other tanks and may be used for sounding bilges, provided that it is not practicable to lead them direct to the tanks or compartments, and subject to any subdivision and damage stability requirements that may apply.

11.12.3 The elbows are to be of heavy construction and adequately supported.

11.13 Sounding arrangements for fuel oil, lubricating oil and other flammable liquids

11.13.1 Safe and efficient means of ascertaining the amount of oil in any storage tank are to be provided.

11.13.2 For fuel oil, lubricating oil and other flammable liquids, closed sounding devices are preferred. Design details of such devices are to be submitted and they are to be tested after fitting on board, to the satisfaction of the Surveyors.

11.13.3 If closed sounding devices are fitted, failure of the device or over filling of the tank is not to result in the release of tank contents. In passenger craft and yachts that are 500 gt or more, such means are not to require penetration below the top of the tank.

11.13.4 Where sounding pipes are used they are not to terminate in any space where risk of ignition or spillage from the sounding pipe might arise. In particular they are not to terminate in public spaces or crew accommodation. Additionally for fuel oil tanks they are not to terminate in machinery spaces. Terminations are to be provided with a suitable means of closure and provision to prevent spillage during refuelling/refilling operations.

11.13.5 Where gauge glasses are used they are to be of the flat type of heat resisting quality, adequately protected from mechanical damage and fitted with self closing valves at the lower ends and at the top ends if these are connected to the tanks below the maximum liquid level.

11.13.6 In yachts and service craft which are not required to comply with the HSC Code, short sounding pipes extending to well-lighted, readily accessible positions above the platform may be fitted in machinery spaces and tunnels. Sounding pipes are to be fitted with cocks having parallel plugs with permanently attached handles located such that, on being released, they automatically close the cocks.

11.13.7 For service craft required to comply with the *SOLAS - International Convention for the Safety of Life at Sea*, as amended (SOLAS 74) and yachts that are 500 gt or more, where short sounding pipes serve tanks containing fuel oil, an additional sounding device of approved type is to be fitted. In addition, a small diameter self-closing test cock is to be fitted below the cock mentioned in *Pt 15, Ch 2, 11.13 Sounding arrangements for fuel oil, lubricating oil and other flammable liquids 11.13.6*, in order to ensure that the sounding pipe is not under pressure from fuel oil before opening up the sounding pipe.

■ *Section 12*
Additional requirements relating to fixed pressure water spray fire-extinguishing systems

12.1 Bilge drainage requirements

12.1.1 Where fixed pressure water spray fire-extinguishing systems are provided for the protection of spaces below the bulkhead deck, the following provisions are to apply:

(a) The drainage system is to be sized to remove no less than 125 per cent of the combined capacity of both the water spraying system pumps and the required number of fire hose nozzles.
(b) The required area of the main and branch bilge pipes for the protected space are to be adequate to ensure a maximum water flow of 2 m/s in each section of the piping.
(c) The drainage system valves are to be operable from outside the protected space at a position in the vicinity of the extinguishing system controls.
(d) Bilge wells on vehicle decks, ro-ro spaces and special category spaces shall be of sufficient holding capacity and shall be arranged at the side shell of the craft at a distance from each other of not more than 40 m in each watertight compartment.

12.1.2 For drainage of vehicle or cargo spaces by gravity, *see Pt 3, Ch 4, 9 Deck drainage*. If led to a closed drain tank, this tank is to be located outside the machinery spaces and provided with a vent pipe leading to a safe location on the open deck.

12.1.3 On craft with closed vehicle spaces, ro-ro spaces and special category spaces, means are to be provided to prevent the blockage of drainage systems from these spaces.

■ *Section 13* Additional requirements for Passenger (B) Craft

13.1 Bilge pumping arrangements

13.1.1 At least three power bilge pumping units are to be fitted connected to the bilge main, one of which may be driven by the propulsion machinery.

13.1.2 For multi-hull craft the bilge pumping units are to be capable of taking suction from the bilge main in any hull of the craft.

13.1.3 The arrangements are to be such that at least one power bilge pump is to be available for use in all flooding conditions which the craft is required to withstand as follows:

(a) one of the required bilge pumps is to be an emergency pump of a reliable submersible type having a source of power located above the waterline after the craft has sustained the maximum assumed damage; or
(b) the bilge pumps and their sources of power are to be so distributed throughout the length of the craft that at least one pump in an undamaged compartment will be available.

13.1.4 Alternatively, fixed submersible bilge pumps may be provided in accordance with the requirements of *Pt 15, Ch 2, 8.3 Capacity of pumps 8.3.4* and *Pt 15, Ch 2, 10 Submersible bilge pump arrangements*.

13.1.5 Distribution boxes, cocks and valves in connection with the bilge pumping system are to be so arranged that, in the event of flooding, one of the bilge pumps may take suction from any compartment.

13.1.6 Damage to a pump or its pipe connecting to the bilge main is not to put the bilge system out of action.

13.1.7 When in addition to the main bilge pumping system an emergency bilge pumping system is provided, it is to be independent of the main system and so arranged that a pump is capable of operating in any compartment under the maximum assumed flooding conditions. In that case only the valves necessary for the operation of the emergency system need be capable of remote operation.

13.1.8 All cocks and valves referred to in *Pt 15, Ch 2, 13.1 Bilge pumping arrangements 13.1.5* which can be remotely operated are to have their controls at their place of operation clearly marked and are to be provided with means to indicate whether they are open or closed.

■ *Section 14* Requirements for small craft which are not required to comply with the HSC Code

14.1 General

14.1.1 These requirements replace *Pt 15, Ch 2, 1 General* to *Pt 15, Ch 2, 10 Submersible bilge pump arrangements*, *Pt 15, Ch 2, 12 Additional requirements relating to fixed pressure water spray fire-extinguishing systems* and *Pt 15, Ch 2, 13 Additional requirements for Passenger (B) Craft* of this Chapter. In general the requirements of *Pt 15, Ch 2, 11 Air, overflow and sounding pipes* are to be complied with, however *Pt 15, Ch 2, 11.4 Air pipe closing appliances 11.4.1* and *Pt 15, Ch 2, 11.9 Sounding arrangements 11.9.3* do not apply.

14.1.2 Bilge and cooling water pipework systems are to be of an approved material, *see Pt 15, Ch 1, 15 Requirements for small craft which are not required to comply with the HSC Code*.

14.2 Shell valves and fittings

14.2.1 All sea inlet and overboard discharges are to be provided with shut off valves or cocks arranged in positions where they are readily accessible at all times.

14.2.2 Where valves, cocks, inlet chests, distance pieces and other sea connections are made of steel or other approved materials of low corrosion resistance, they are to be suitably protected against wastage.

14.3 Fittings for steel and aluminium alloy hulls

14.3.1 All suction and discharge valves and cocks secured direct to the shell plating are to be secured by studs screwed into heavy pads welded to the plating. The stud holes are not to penetrate the plating.

14.3.2 Alternatively, distance pieces of short rigid construction and made of approved material may be fitted between the valve and the shell plating. The thickness of such pipes is to be equivalent to shell thickness. Distance pieces of steel may be welded to steel shell plating and distance pieces of aluminium alloy may be welded to aluminium alloy shell plating.

14.3.3 Valves or fittings attached direct to the plating of tanks, and to bulkheads or flats which are required to be of watertight construction, are to be secured by means of studs or tap bolts screwed through bulkhead pieces welded to the plating, and not by bolts passing through clearance holes. For tanks, the stud or tap bolt holes are not to penetrate the plating.

14.4 Fittings for composite hulls

14.4.1 The openings in the shell or planking are to have suitably reinforced areas or pads into which the attached fittings are to be spigoted.

14.4.2 Valves or fittings are to be secured with an external ring under the bolt heads. The ring is to be of copper nickel alloy, bronze, dezincification resistant brass or other material approved for use in sea-water.

14.4.3 Valves or cocks up to 50 mm bore may be attached to spigot pieces or hull fittings having an external collar and internal nut.

14.4.4 Valves or cocks over 50 mm bore are to be flanged and attached as per *Pt 15, Ch 2, 14.4 Fittings for composite hulls 14.4.2*.

14.4.5 Valves or fittings attached direct to the plating of tanks, and to bulkheads or flats which are required to be of watertight construction, are, in general, to be secured as detailed in *Pt 15, Ch 2, 14.4 Fittings for composite hulls 14.4.1* to *Pt 15, Ch 2, 14.4 Fittings for composite hulls 14.4.4*, having regard to the intended service. Details are to be submitted for consideration.

14.5 Bilge pumping arrangements

14.5.1 An efficient bilge pumping system is to be fitted having suctions and means of drainage so arranged that any water which may enter any compartment can be pumped overboard.

14.5.2 The system is to be tested on completion of the craft to ensure that all limber holes are free and that under normal conditions of trim any bilge water can drain to an appropriate suction.

14.5.3 The arrangement of pumps, valves, cocks, pipes and sea connections is to be such as to prevent water entering the craft accidentally or the possibility of one watertight compartment being placed in communication with another.

14.5.4 Readily accessible strum boxes are to be fitted at the open ends of tail pipes.

14.5.5 The perforations in the strum boxes are to be not greater than 10 mm diameter and the combined area is to be not less than twice that required for the bilge suction pipe.

14.5.6 Where a collision bulkhead is fitted, the fore peak dry space is to be drained either by a branch suction to the main bilge line or by a manual pump. Alternatively, it may be drained to the adjacent compartment by means of a self closing drain cock which is to be readily accessible under all conditions.

14.5.7 Where a bilge main is fitted, the internal diameter *d* of the main and the branch suction pipes is to be not less than that required by the following formula:

$$d = \frac{L}{1,2} + 25 \text{ mm}$$

where

L = length of craft, in metres

14.6 Pumps on bilge service and their connections

14.6.1 Not less than one power pump and one manual bilge pump are to be provided. Both pumps are to be arranged to take suction from the bilge main or suction valve chest as applicable.

14.6.2 The power driven pumps may be used for other services such as deck washing, fire extinguishing or standby cooling water duty but not for pumping fuel oil or other flammable liquids.

14.6.3 The total capacity Q_t of the bilge pumps is to be not less than required by the following formula:

$$Q_t = 1,5(d - 25) - 6,7 \text{ m}^3/\text{hour}$$

where

d = is as defined in *Pt 15, Ch 2, 14.5 Bilge pumping arrangements 14.5.7*.

Q_t = is in no case to be less than 3 m^3/hour.

14.6.4 A reduction in capacity of one pump may be permitted provided the deficiency is made good by an excess capacity of the other pump or by an additional pump. In no case is this deficiency to be more than 40 per cent of the Rule capacity.

14.6.5 Pumps on bilge service are to be of the self-priming type.

14.6.6 The bilge pumps are to be connected to a common bilge line provided with a branch connection to each compartment.

14.6.7 A non-return valve is to be fitted between each bilge pump and the bilge main.

14.6.8 Non-return valves are to be fitted in each branch bilge suction from the main bilge line.

14.6.9 Power pumps may be driven by the main engine, an auxiliary engine or by an electric motor.

14.6.10 The power pump is to be provided with a suction enabling it to pump directly from the engine space in addition to the suction from the main bilge line. This direct bilge suction is to be controlled by a screw down non-return valve or equivalent.

14.6.11 Manual bilge pumps are to be capable of being operated from readily accessible positions above the waterline.

14.6.12 As an alternative to fitting a bilge main, individual submersible pumps may be fitted. In this case the arrangements are to be in accordance with the requirements of *Pt 15, Ch 2, 8 Pumps on bilge service* and *Pt 15, Ch 2, 10 Submersible bilge pump arrangements* of this Chapter, as applicable.

■ *Section 15*
Requirements for yachts and service craft of 24 m or greater in length, which are not required to comply with the HSC Code

15.1 General

15.1.1 The requirements of *Pt 15, Ch 2, 1 General*, *Pt 15, Ch 2, 2 Construction and installation*, *Pt 15, Ch 2, 3 Shell valves and fittings (other than those on scuppers and sanitary discharges)*, *Pt 15, Ch 2, 11 Air, overflow and sounding pipes* and *Pt 15, Ch 2, 12 Additional requirements relating to fixed pressure water spray fire-extinguishing systems* of this Chapter are generally applicable. The remaining *Pt 15, Ch 2, 4 Bilge pumping and drainage systems* of this Chapter concerning the requirements for bilge pumping and drainage systems are replaced by the requirements given in *Pt 15, Ch 2, 15.2 Drainage of spaces containing low flashpoint fuel* to *Pt 15, Ch 2, 15.30 Bilge level detection*.

15.2 Drainage of spaces containing low flashpoint fuel

15.2.1 Where it is intended to carry vehicles or craft with fuel in their tanks having a flashpoint (closed-cup test) less than 60°C for their own propulsion or having re-fuelling facilities for such vehicles or craft, a separate bilge system is to be provided.

15.2.2 The bilge system is to be designed to prevent pumping of flammable liquids through piping and pumps in machinery, accommodation or any other spaces where a source of ignition may exist.

15.2.3 For special requirements relating to the separate bilge system, *see Pt 15, Ch 2, 12 Additional requirements relating to fixed pressure water spray fire-extinguishing systems*, *Pt 15, Ch 2, 15.12 Sizes of bilge suction pipes 15.12.5*, *Pt 15, Ch 2, 15.14 Pumps on bilge service and their connections 15.14.7* and *Pt 15, Ch 2, 15.16 Capacity of pumps 15.16.4*.

15.3 Drainage of compartments, other than machinery spaces

15.3.1 All craft are to be provided with efficient pumping plant having the suctions and means for drainage so arranged that any water within any compartment of the craft, or any watertight section of any compartment, can be pumped out through at least one suction when the craft is on an even keel and is either upright or has a list of not more than 5°. For yachts a list of not more than 10 ° shall be assumed. For this purpose, wing suctions will generally be necessary, except in short, narrow compartments where one suction can provide effective drainage under the above conditions.

15.3.2 In the case of dry compartments, the suctions required by *Pt 15, Ch 2, 15.3 Drainage of compartments, other than machinery spaces 15.3.1* are, except where otherwise stated, to be branch bilge suctions, i.e. suctions connected to a main bilge line.

15.3.3 For a normally inaccessible small void compartment such as an echo sounding compartment, which is accessed from within a normally inaccessible space such as a forepeak tank, alternative drainage arrangements to those required by *Pt 15, Ch 2, 15.3 Drainage of compartments, other than machinery spaces 15.3.1* may be considered. For such arrangements, a warning notice is to be located in a prominent position specifying the precautions to be taken prior opening the manhole of the small void compartment. Means are to be provided to indicate flooding of the compartment without opening, such as fitting indicator plugs to the manhole. Drainage arrangements are to be submitted to LR for approval.

15.4 Tanks and cofferdams

15.4.1 All tanks (including double bottom tanks), whether used for water ballast, fuel oil or liquid cargoes, are to be provided with suction pipes, led to suitable power pumps, from the after end of each tank.

15.4.2 In general, the drainage arrangements are to be in accordance with *Pt 15, Ch 2, 15.3 Drainage of compartments, other than machinery spaces*. However, where the tanks are divided by longitudinal watertight bulkheads or girders into two or more tanks, a single suction pipe, led to the after end of each tank, will normally be acceptable.

15.4.3 Similar drainage arrangements are to be provided for cofferdams, except that the suctions may be led to the main bilge line.

15.5 Fore and after peaks

15.5.1 Fuel oil, lubrication oil and other flammable oils are not to be carried in forepeak tanks.

15.5.2 Where the peaks are used as tanks, a power pump suction is to be led to each tank, except in the case of small tanks used for the carriage of domestic fresh water, where hand pumps may be used.

15.5.3 Where the peaks are not used as tanks, and main bilge line suctions are not fitted, drainage of both peaks may be effected by hand pump suctions, provided that the suction lift is well within the capacity of the pumps. Drainage of the after peak may be effected by means of a self-closing cock fitted in a well lighted and readily accessible position.

15.5.4 Pipes piercing the collision bulkhead are to be fitted with suitable valves secured to the bulkhead inside the forepeak. The valves are to be operable from an accessible position above the freeboard deck on service craft and above the bulkhead deck on yachts. An indicator is to be provided to show whether the valves are open or closed. These valves may be fitted on the after side of the collision bulkhead, provided that they are readily accessible under all service conditions and the space in which they are located is not a cargo space. In the latter case, the valves need not be operable from above the freeboard or bulkhead deck.

15.5.5 On service craft required to comply with the *International Convention for the Safety of Life at Sea, 1974*, as amended (SOLAS 74) and on yachts, valves on the collision bulkhead are to be of a screw-down type.

15.5.6 The collision bulkhead is not to be pierced below the bulkhead deck by more than one pipe for transferring the contents of the fore peak. Where the fore peak is divided into two compartments, the collision bulkhead may be pierced below the bulkhead deck by two pipes (i.e. one for each compartment) provided there is no practical alternative to the fitting of a second pipe. Each pipe is to be provided with a valve as in *Pt 15, Ch 2, 15.5 Fore and after peaks 15.5.4* and *Pt 15, Ch 2, 15.5 Fore and after peaks 15.5.5*.

15.5.7 For yachts, when it is necessary to lead additional pipes to machinery equipment located inside the forepeak, details are to be included in the documentation required by *Pt 15, Ch 1, 2.1 Plans and information*. Attention is drawn to the provision of additional penetrations in the collision bulkhead being restricted by the UK MCA LY3 Code and an exemption from the National Authority of the country in which the ship is to be registered will be required.

15.6 Spaces above fore peaks, after peaks and machinery spaces

15.6.1 Provision is to be made for the drainage of the chain locker and watertight compartments above the fore peak tank by hand or power pump suctions.

15.6.2 Steering gear compartments or other small enclosed spaces situated above the after peak tank are to be provided with suitable means of drainage, either by hand or power pump bilge suctions.

15.6.3 The compartments referred to in *Pt 15, Ch 2, 15.6 Spaces above fore peaks, after peaks and machinery spaces 15.6.1* may be drained by scuppers of not less than 38 mm bore, discharging to the tunnel or machinery space and fitted with self-closing cocks situated in well lighted and visible positions.

15.7 Maintenance of integrity of bulkheads

15.7.1 The intactness of the machinery space bulkheads, and of tunnel plating required to be of watertight construction, is not to be impaired by the fitting of scuppers discharging to machinery space or tunnels from adjacent compartments which are situated below the bulkhead deck.

15.7.2 No drain valve or cock is to be fitted to the collision bulkhead. Drain valves or cocks are not to be fitted to other watertight bulkheads if alternative means of drainage are practicable.

15.8 Bilge drainage of machinery space

15.8.1 The bilge drainage arrangements in the machinery space are to comply with *Pt 15, Ch 2, 15.3 Drainage of compartments, other than machinery spaces* except that the arrangements are to be such that any water which may enter this compartment can be pumped out through at least two bilge suctions when the craft is on an even keel, and is either upright or has a list of not more than 5°. For yachts a list of not more than 10 ° shall be assumed. One of these suctions is to be a branch bilge suction, i.e. a suction connected to the main bilge line, and the other is to be a direct bilge suction, i.e. a suction led direct to an independent power pump.

15.9 Separate machinery spaces

15.9.1 Where the machinery space is divided by watertight bulkheads to separate the auxiliary engine room(s) from the main engine room, the bilge drainage arrangements for the auxiliary engine room(s) are to be the same as for compartments, other than machinery spaces, referred to in *Pt 15, Ch 2, 15.3 Drainage of compartments, other than machinery spaces 15.3.1*.

15.9.2 In addition to the requirements of *Pt 15, Ch 2, 15.9 Separate machinery spaces 15.9.1*, at least one direct suction, led to an independent power pump, is to be fitted in each compartment.

15.9.3 In yachts, each bilge pump in *Pt 15, Ch 2, 15.14 Pumps on bilge service and their connections 15.14.5* is to have a direct bilge suction from the space in which it is situated. *See also Pt 15, Ch 2, 15.19 Direct bilge suction 15.19.1*.

15.10 Machinery space with double bottom

15.10.1 Where the double bottom extends the full length of the machinery space and forms bilges at the wings, it will be necessary to provide one branch and one direct bilge suction at each side.

15.10.2 Where the double bottom plating extends the full length and breadth of the compartment, one branch bilge suction and one direct bilge suction are to be led to each of two bilge wells, situated one at each side.

15.10.3 Where there is no double bottom and the rise of floor is not less than 5° on service craft and 10 ° on yachts, one branch and one direct bilge suction are to be led to accessible positions as near to the centreline as practicable.

15.11 Machinery space - Emergency bilge drainage

15.11.1 In addition to the bilge suctions detailed in *Pt 15, Ch 2, 15.8 Bilge drainage of machinery space* and*Pt 15, Ch 2, 15.9 Separate machinery spaces*, an emergency bilge suction is to be provided in each main machinery space. This suction is to be led to the main cooling water pump from a suitable low level in the machinery space and is to be fitted with a screw-down non-return valve having the spindle so extended that the hand wheel is not less than 460 mm above the bottom platform.

15.11.2 Where two or more cooling water pumps are provided, each capable of supplying cooling water for normal power, only one pump need be fitted with an emergency bilge suction.

15.11.3 Where main cooling water pumps are not suitable for bilge pumping duties, the emergency bilge suction is to be led to the largest available power pump, which is not a bilge pump.

15.11.4 Emergency bilge suction valve nameplates are to be marked `For emergency use only'.

15.12 Sizes of bilge suction pipes

15.12.1 The diameter, d_m, of the main bilge line is to be not less than that required by the following formula, to the nearest 5 mm, but in no case is the diameter to be less than that required for any branch bilge suction:

$$d_m = 1,68\sqrt{L(B + D)} + 25 \text{ mm}$$

where

d_m = internal diameter of main bilge line, in mm

B = greatest moulded breadth of craft, in metres, for mono-hull craft

= greatest moulded breadth of a single hull in metres, for multi-hull craft

D = moulded depth to bulkhead deck, in metres

L = Rule length of craft in metres, for service craft

= length as defined in the International Convention on Load Lines in metres, for yachts.

15.12.2 The diameter d_b, of branch bilge suction pipes to cargo and machinery spaces is to be not less than required by the following formula, to the nearest 5 mm, but in no case is the diameter of any suction to be less than 50 mm:

$$d_b = 2,15\sqrt{C(B + D)} + 25 \text{ mm}$$

where

d_b = internal diameter of branch bilge suction, in mm

C = length of compartment, in metres

B and *D* are as defined in *Pt 15, Ch 2, 15.12 Sizes of bilge suction pipes 15.12.1*

15.12.3 The direct bilge suctions in the machinery space are not to be of a diameter less than that required for the main bilge line.

15.12.4 For sizes of emergency bilge suctions, *see Pt 15, Ch 2, 15.11 Machinery space - Emergency bilge drainage*.

15.12.5 The cross-sectional area of the main bilge pipe of the system required by *Pt 15, Ch 2, 15.2 Drainage of spaces containing low flashpoint fuel* is to be not less than twice that required for the branch bilge suction pipes in the space.

15.13 Distribution chest branch pipes

15.13.1 The area of each branch pipe connecting the bilge main to a distribution chest is to be not less than the sum of the areas required by the Rules for the two largest branch bilge suction pipes connected to that chest, but need not be greater than that required for the main bilge line.

15.14 Pumps on bilge service and their connections

15.14.1 For service craft, at least two power bilge pumping units are to be provided in the machinery space. One of these units may be worked from the main engines and the other is to be independently driven.

15.14.2 For multi-hull service craft, the power bilge pumping units in *Pt 15, Ch 2, 15.14 Pumps on bilge service and their connections 15.14.1* are to take suction from the bilge main in each hull. Where the bilge system in each hull is entirely separate, at least two bilge pumping units in each hull are to be provided.

15.14.3 Each unit may consist of one or more pumps connected to the main bilge line, provided that their combined capacity is adequate.

15.14.4 A bilge ejector in combination with a high pressure sea-water pump may be accepted as a substitute for an independent bilge pump as required by *Pt 15, Ch 2, 15.14 Pumps on bilge service and their connections 15.14.1*.

15.14.5 For yachts, at least two power bilge pumps are to be provided, both of which are to be independently driven. The arrangement of the bilge pumps and their individual supplies shall be such that, in the event of any one compartment being

flooded at least one of the pumps is available for removing water from the flooded space and adjacent compartments. At least one pump shall be located in the machinery space.

15.14.6 For multi-hull yachts, the power bilge pumps in *Pt 15, Ch 2, 15.14 Pumps on bilge service and their connections 15.14.5* are to take suction from the bilge main in each hull. Where the bilge system in each hull is entirely separate, at least two bilge pumps in each hull are to be provided.

15.14.7 The bilge system required by *Pt 15, Ch 2, 15.2 Drainage of spaces containing low flashpoint fuel* is to be served by at least two dedicated power bilge pumps or bilge ejectors, except in the case of small fuel storage spaces where one bilge pump or ejector may be accepted.

15.14.8 Special consideration will be given to the number of pumps for small craft and, in general, if there is a class notation restricting a small craft to harbour or river service, a hand pump may be accepted in lieu of one of the bilge pumping units.

15.15 General service pumps

15.15.1 The bilge pumping units, or pumps, required by *Pt 15, Ch 2, 15.14 Pumps on bilge service and their connections* may also be used for ballast, fire or general service duties of an intermittent nature, but they are to be immediately available for bilge duty when required.

15.16 Capacity of pumps

15.16.1 Each bilge pumping unit or bilge pump in *Pt 15, Ch 2, 15.14 Pumps on bilge service and their connections* (except *Pt 15, Ch 2, 15.14 Pumps on bilge service and their connections 15.14.7*) is to be connected to the main bilge line and is to be capable of giving a speed of water through the Rule size of main bilge line of not less than 2 m/s.

15.16.2 The capacity Q of each bilge pumping unit or bilge pump is to be not less than required by the following formula:

$$Q = \frac{5,75}{10^3} d_m^2$$

where

d_m = Rule internal diameter of main bilge line, in mm

Q = capacity, in m^3/hour

15.16.3 In service craft, where one bilge pumping unit is of slightly less than Rule capacity, the deficiency may be made good by an excess capacity of the other unit. In general, the deficiency is to be limited to 30 per cent.

15.16.4 The capacity of each bilge pump or bilge ejector in *Pt 15, Ch 2, 15.14 Pumps on bilge service and their connections 15.14.7* is to be not less than that calculated by the formula in *Pt 15, Ch 2, 15.16 Capacity of pumps 15.16.2*. However, d_m may be replaced by the diameter of the main bilge pipe calculated in *Pt 15, Ch 2, 15.12 Sizes of bilge suction pipes 15.12.5*.

15.17 Self-priming pumps

15.17.1 All power pumps which are essential for bilge services are to be of the self-priming type, unless an approved central priming system is provided for these pumps. Details of this system are to be submitted.

15.17.2 Cooling water pumps having emergency bilge suctions need not be of the self-priming type.

15.18 Pump connections

15.18.1 The connections at the bilge pumps are to be such that one unit may continue in operation when the other unit is being opened up for overhaul.

15.18.2 Pumps required for essential services are not to be connected to a common suction or discharge chest or pipe unless the arrangements are such that the working of any pumps so connected is unaffected by the other pumps being in operation at the same time.

15.19 Direct bilge suction

15.19.1 The direct bilge suctions in the machinery space are to be led to independent power pumps, and the arrangements are to be such that these direct suctions can be used independently of the main bilge line suctions. In yachts, when only one independent pump is available in the machinery space, both direct bilges suctions required by *Pt 15, Ch 2, 15.10 Machinery space with double bottom 15.10.2* may be led to this pump.

15.20 Main bilge line suctions

15.20.1 Suctions from the main bilge line, i.e. branch bilge suctions, are to be arranged to draw water from any compartment within the craft, excepting small spaces such as those mentioned in *Pt 15, Ch 2, 15.5 Fore and after peaks* and *Pt 15, Ch 2, 15.6 Spaces above fore peaks, after peaks and machinery spaces* where manual pump suctions are accepted, and are not to be of smaller diameter than that required by the formula in *Pt 15, Ch 2, 15.12 Sizes of bilge suction pipes 15.12.2*.

15.21 Prevention of communication between compartments

15.21.1 The arrangement of valves, cocks and their connections is to be such as to prevent the possibility of one watertight compartment being placed in communication with another, or of dry cargo spaces, machinery spaces or other dry compartments being placed in communication with the sea or with tanks. For this purpose, screw-down non-return valves are to be provided in the following fittings:

- Bilge valve distribution chests.
- Bilge suction hose connections, whether fitted directly to the pump or on the main bilge line.
- Direct bilge suctions and bilge pump connections to main bilge line.

15.22 Isolation of bilge system

15.22.1 Bilge pipes which are required for draining cargo or machinery spaces are to be entirely distinct from sea inlet pipes or from pipes which may be used for filling or emptying spaces where water or oil is carried. This does not, however, exclude a bilge ejection connection, a connecting pipe from a pump to its suction valve chest, or a deep tank suction pipe suitably connected through a change-over device to a bilge, ballast or oil line.

15.23 Machinery space suctions - Mud boxes

15.23.1 Suctions for bilge drainage in machinery spaces and tunnels, other than emergency suctions, are to be led from easily accessible mud boxes fitted with straight tail pipes to the bilges and having covers secured in such a manner as to permit their being expeditiously opened or closed. Strum boxes are not to be fitted to the lower ends of these tail pipes or to the emergency bilge suctions.

15.24 Other compartment suctions - Strum boxes

15.24.1 The open ends of bilge suctions in compartments outside machinery spaces and tunnels are to be enclosed in strum boxes having perforations of not more than 10 mm diameter, whose combined area is not less than twice that required for the suction pipe. The boxes are to be so constructed that they can be cleared without breaking any joint of the suction pipe.

15.25 Tail pipes

15.25.1 The distance between the foot of all bilge tail pipes and the bottom of the bilge well is to be adequate to allow a full flow of water and to facilitate cleaning.

15.26 Location of fittings

15.26.1 Bilge valves, cocks and mud boxes are to be fitted at, or above, the machinery space platforms.

15.26.2 Where relief valves are fitted to pumps having sea connections, these valves are to be fitted in readily visible positions above the platform. The arrangements are to be such that any discharge from the relief valves will also be readily visible.

15.27 Bilge pipes in way of double bottom tanks

15.27.1 Bilge suction pipes are not to be led through double bottom tanks if it is possible to avoid doing so.

15.27.2 Bilge pipes which have to pass through these tanks are to have a minimum wall thickness of 6.3mm. The thickness of pipes made from material other than steel will be specially considered.

15.27.3 Expansion bends, not glands, are to be fitted to these pipes within the tanks, and the pipes are to be tested, after installation, to the same pressure as the tanks through which they pass.

15.28 Bilge non-return valves

15.28.1 Where non-return valves are fitted to the open ends of bilge suction pipes in order to decrease the risk of flooding, they are to be of an approved type which does not offer undue obstruction to the flow of water.

15.29 Arrangement and control of bilge valves in yachts

15.29.1 Distribution boxes, valves and cocks in connection with the bilge pumping arrangements are to be so arranged that, in the event of flooding of any one compartment, one of the bilge pumps may be operative on that space and adjacent compartments. For this purpose, it may be necessary to arrange for remote control of the bilge suction valves from above the bulkhead deck.

15.29.2 All valves and cocks mentioned in *Pt 15, Ch 2, 15.29 Arrangement and control of bilge valves in yachts 15.29.1* which can be operated from above the bulkhead deck are to have their controls at their place of operation clearly marked and provided with means to indicate whether they are open or closed.

15.30 Bilge level detection

15.30.1 Where **UMS** (Unattended Machinery Space) notation is to be assigned, level alarms are to be provided in machinery space bilges, *see Pt 16, Ch 1, 4.7 Bilge level detection 4.7.2*.

15.30.2 On yachts, high level alarms are to be provided in bilges into which fuel or other oils of similar or higher fire risk could collect, under either normal or fault conditions.

15.30.3 High level alarms are to be provided in bilges of spaces containing low flashpoint fuel.

15.30.4 In addition to the requirements of this Section, for yachts, attention is to be given to any relevant requirements of the UK MCA LY3 Code.

■ *Section 16*
Requirements for Air Cushion Vehicles

16.1 General

16.1.1 At least three copies of the following diagrammatic plans are to be submitted together with a general description of each system, indicating operating pressures and temperatures etc. safety devices incorporated and means of protection against corrosion and contamination:

- Fuel oil.
- Lubricating oil.
- Hydraulic and pneumatic systems.
- Pumping arrangements for draining and trimming.
- Air filtering to power units.

16.1.2 Reference is to be made to the *Rules for the Classification of Air Cushion Vehicles, July 2021*.

■ *Section 1* Application

1.1 Applicability of requirements

1.1.1 The requirements of *Pt 15, Ch 3, 2 General requirements* of this Chapter apply to piping systems on mono-hull and multi-hull craft except where modified by *Pt 15, Ch 3, 10 Special requirements for multi-hull craft* as applicable.

1.1.2 Special requirements for multi-hull craft are given in *Pt 15, Ch 3, 10 Special requirements for multi-hull craft*.

1.1.3 These requirements satisfy the relevant design and construction requirements of the HSC Code. They are also applicable to yachts and service craft of 24 m or more not required to comply with the Code. The requirements for yachts satisfy the relevant requirements of the UK MCA LY3 Code.

1.1.4 Requirements for Passenger (A) Craft are given in *Pt 15, Ch 3, 11 Requirements for Passenger (A) Craft*.

1.1.5 Requirements for small craft not required to comply with the HSC Code are given in *Pt 15, Ch 3, 12 Requirements for small craft which are not required to comply with the HSC Code*.

1.1.6 Special consideration shall be given to passenger craft not required to comply with the HSC Code.

1.1.7 In addition to the requirements of this Chapter, attention is to be given to any relevant statutory requirements of the National Authority of the country in which the craft is to be registered.

■ *Section 2* General requirements

2.1 General

2.1.1 The maximum working pressure in any part of a fluid system is not to be greater than the design pressure.

2.1.2 Where the design pressure of a system component, such as a valve or a fitting, is less than that for the pipe or tubing, the system pressure is to be limited to the lowest of the component design pressures. Every system which may be exposed to pressures higher than the design pressure is to be safeguarded by appropriate relief devices.

2.1.3 Materials used in piping systems are to be compatible with the fluid conveyed and due regard given to the risk of fire. Non-metallic piping material may be permitted in certain systems, provided the integrity of the hull and watertight decks and bulkheads is maintained.

2.1.4 The design of pipework systems is to be in accordance with the requirements of *Pt 15, Ch 1 Piping Design Requirements*.

2.2 Fuel oil sampling

2.2.1 Sampling points are to be provided within the fuel oil system. The design and location of sampling points is to enable samples of fuel oil to be taken easily and in a safe manner.

2.2.2 The position of a sampling point is to be such that the sample of the fuel oil is representative of the fuel oil quality at its location within the system, e.g. by ensuring steady state flow past the sampling point.

Note Samples taken from sounding pipes and tank drain cocks are not considered to be representative of the tank’s contents.

2.2.3 Sampling points are to be located so as to reduce the possibility of fuel oil coming into contact with any heated surface or electrical equipment under reasonably foreseeable operating conditions and therefore shall be positioned as far away as possible from such surfaces or equipment. Where contact is still likely, positions are to be shielded from any heated surface or electrical equipment. The shielding shall be sturdy enough to endure leaks, splashes or spray under design pressure of the fuel oil supply line.

2.2.4 A sampling point or points shall be provided:

(a) Taking into account different fuel oil grades being used for the fuel oil combustion machinery item;
(b) Downstream of the in-use fuel oil service tank; and
(c) As close to the fuel oil combustion machinery as safely feasible taking into account the type of fuel oil, flow-rate, temperature, and pressure behind the selected sampling point.

2.2.5 The sampling arrangements within the machinery space are to be capable of safely providing samples when the machinery is running and are to be provided with isolating valves and cocks of the self-closing type.

■ *Section 3*
Fuel oil storage

3.1 Flash point

3.1.1 The flash point (closed cup test) of fuel oil for use in craft classed for unrestricted service is in general to be not less than 60°C. For emergency generator engines, a flash point of not less than 43°C is permissible.

3.1.2 Fuel oil with a flash point lower than 60°C may be used in craft intended for restricted service where it can be demonstrated that the temperature of machinery spaces will always be 10°C below the flash point of the fuel oil.

3.1.3 The use of fuel oil with a flash point below 43°C is not recommended. However, fuel oil with a lower flash point, but not lower than 35°C, may be used in gas turbines only subject to compliance with the provisions specified in *Pt 15, Ch 3, 5 Low flash point fuels*.

3.1.4 Proposals for the use or carriage of fuel oil with a lower flash point will be specially considered.

3.2 Fuel oil storage arrangements

3.2.1 Tanks containing fuel oil are to be separated from passenger, crew and baggage compartments by vapour-proof enclosures or cofferdams which are suitably ventilated and drained.

3.2.2 Fuel oil tanks are not to be located in or adjacent to major fire hazard areas.

3.2.3 Fuel oil is not to be carried forward of the area for which public spaces or crew accommodation are permitted.

3.2.4 No fuel oil tank is to be situated where spillage or leakage therefrom can constitute a hazard by falling on heated surfaces.

3.2.5 Safe and efficient means of ascertaining the amount of fuel oil contained in any fuel oil tank is to be provided, *see also Pt 15, Ch 2, 11.9 Sounding arrangements*.

3.2.6 Fuel oil tanks are to be provided with self-closing valves or cocks for draining water from the bottom of the tanks.

3.2.7 As far as practicable, all parts of the fuel oil system containing heated oil under pressure exceeding 2 bar are not to be placed in a concealed position such that defects and leakage cannot be readily observed. The machinery spaces in way of such parts of the fuel oil system are to be adequately illuminated.

3.2.8 Fuel oil tanks are to be provided with oil-tight drip trays of sufficient capacity having suitable drainage arrangements.

3.2.9 In general fuel oil tanks are not to be used for carriage of water ballast. Where this is unavoidable the fuel transfer system is to be isolated from the ballast system and either oily water separating equipment is to be installed, or discharge to shore facilities provided, in accordance with the requirements of the *International Convention for the Prevention of Pollution from Ships* in force.

3.3 Fuel oil storage arrangements for yachts and service craft of 24 m or greater in length, which are not required to comply with the HSC Code

3.3.1 Fuel oil tanks are normally to be located outside machinery spaces and other areas of major fire hazard.

3.3.2 Where structural tanks are located adjacent to machinery spaces they are to be arranged such that the area of the tank common with the machinery space is kept to a minimum. In craft constructed of aluminium or other heat sensitive material the tanks are to be suitably protected against the effect of fire in the machinery space.

3.3.3 Where free standing tanks are fitted in machinery spaces they are to be of steel or equivalent material and positioned in an oil tight drip tray of ample size having suitable drainage arrangements to a spill oil tank.

3.3.4 For yachts that are 500 gt or more, free standing fuel oil tanks are not to be fitted in Category ‘A’ machinery spaces. *See also* the additional requirements in *Pt 17, Ch 3, 3.17 Fuel oil arrangements 3.17.3*.

3.3.5 The requirements of *Pt 15, Ch 3, 3.2 Fuel oil storage arrangements 3.2.4* to *Pt 15, Ch 3, 3.2 Fuel oil storage arrangements 3.2.9* are to be complied with. Where free standing tanks are fitted they are to comply with the requirements of *Pt 15, Ch 3, 12.3 Separate fuel oil tanks 12.3.1* to *Pt 15, Ch 3, 12.3 Separate fuel oil tanks 12.3.3*.

3.4 Unattended machinery

3.4.1 Where machinery is fitted with automatic or remote controls so that under normal operating conditions it does not require any manual intervention by the operators, the requirements of *Pt 15, Ch 3, 3.4 Unattended machinery 3.4.2* to *Pt 15, Ch 3, 3.4 Unattended machinery 3.4.5* apply.

3.4.2 Where daily service tanks are filled automatically or by remote control, means are to be provided to prevent overflow spillages.

3.4.3 Other equipment which treats flammable liquid automatically, such as fuel oil purifiers, are to have arrangements to prevent spillage of the liquid through overflow or malfunction of seals.

3.4.4 Alarms are to be provided for purifier broken water seal and high oil inlet temperature.

3.4.5 Where daily service fuel oil tanks or settling tanks are fitted with heating arrangements, a high temperature alarm is to be provided if the flash point of the oil can be exceeded. This alarm is to be separate from the temperature control system.

3.4.6 Fuel oil service tanks are to be provided with high and low level alarms. Where a common overflow tank is fitted, a high level alarm in the common overflow tank may be accepted.

3.4.7 Oil and gas dual-fired systems for boilers and engines are to be provided with indication to show which fuel is in use.

Section 4
Fuel oil systems

4.1 Fuel oil supply to main and auxiliary engines

4.1.1 Two or more filters are to be fitted in the fuel oil supply lines to the main and auxiliary engines, and the arrangements are to be such that any filter can be cleaned without interrupting the supply of filtered fuel oil to the engines.

4.2 Booster pumps

4.2.1 Where a fuel oil booster pump is fitted, which is essential to the operation of the main engine, a standby pump is to be provided. The standby pump is to be connected ready for immediate use.

4.2.2 Where two or more main engines are fitted, each with its own pump, and the craft cannot navigate safely with one of the main engines out of action, the main engines are to be provided with a standby pump as detailed in *Pt 15, Ch 3, 4.2 Booster pumps 4.2.1*.

4.2.3 Where two or more main engines are fitted, each with its own pump, and the craft can navigate safely with one of the main engines out of action, standby pumps are not required.

4.2.4 Fuel oil booster pumps are to be suitable for all types of fuel used by the craft.

4.3 Fuel valve cooling pumps

4.3.1 Where pumps are provided for fuel valve cooling, the arrangements are to be in accordance with *Pt 15, Ch 3, 4.2 Booster pumps 4.2.1* to *Pt 15, Ch 3, 4.2 Booster pumps 4.2.3*.

4.4 Transfer pumps

4.4.1 Where a power driven pump is necessary for transferring fuel oil, a standby pump is to be provided and connected ready for use. The standby pump may be a manual pump. Alternatively, emergency connections may be made to another suitable power driven pump.

4.5 Control of pumps

4.5.1 All independently driven fuel oil transfer and pressure pumps are to be capable of being stopped locally and from a position outside of the space in which they are located. The remote stop position is always to be accessible in the event of fire occurring in the space in which these pumps are located.

4.6 Relief valves on pumps

4.6.1 All pumps which are capable of developing a pressure exceeding the design pressure of the system are to be provided with relief valves. Each relief valve is to be in closed circuit, i.e. arranged to discharge back to the suction side of the pump and to effectively limit the pump discharge pressure to the design pressure of the system.

4.7 Pump connections

4.7.1 Valves or cocks are to be interposed between the pumps and the suction and discharge pipes, in order that any pump may be shut off for opening up and overhauling.

4.8 Low pressure pipes

4.8.1 Transfer, suction and other low pressure oil pipes and all pipes passing through oil storage tanks are to be suitable for a working pressure of not less than 7 bar.

4.9 Valves on deep tanks and their control arrangements

4.9.1 Every fuel oil suction pipe from a storage, settling or daily service tank situated above the double bottom, and every fuel oil levelling pipe, is to be fitted with a valve or cock secured to the tank.

4.9.2 In machinery spaces such valves and cocks are to be capable of being closed locally and from positions outside these spaces which will always be accessible in the event of fire occurring in these spaces. Instructions for closing the valves or cocks are to be indicated at the valves and cocks and at the remote control positions.

4.9.3 In the case of tanks of less than 0,5 m^3, consideration will be given to the omission of remote controls for craft not required to comply with the HSC Code.

4.9.4 Every fuel oil suction pipe which is led into the machinery spaces, from a deep tank outside these spaces, is to be fitted in the machinery space with a valve controlled as in *Pt 15, Ch 3, 4.9 Valves on deep tanks and their control arrangements 4.9.2* except where the valve on the tank is already capable of being closed from an accessible position above the bulkhead deck.

4.9.5 Where the filling pipes to deep oil tanks are not connected to the tanks near the top, they are to be provided with non-return valves at the tanks or with valves or cocks fitted and controlled as in *Pt 15, Ch 3, 4.9 Valves on deep tanks and their control arrangements 4.9.2*.

4.10 Filling arrangements

4.10.1 Filling stations are to be isolated from other spaces and are to be efficiently drained and ventilated.

4.10.2 When the tanks are filled from shore under pressure, provision is to be made against overpressure in the filling pipelines. Any relief valve fitted for this purpose is to discharge to an overflow tank or other safe position.

4.11 Precautions against fire

4.11.1 Pipes, valves and couplings conveying fuel oil are to be installed, screened or otherwise suitably protected, to avoid spray or leakages onto hot surfaces, into machinery air intakes, or other sources of ignition such as electrical equipment. Pipe joints are to be kept to a minimum and where provided are to be of a type acceptable to LR.

4.11.2 Pumps, filters and heaters are to be located to avoid oil spray or oil leakages onto hot surfaces or other sources of ignition, or onto rotating machinery parts. Where necessary, shielding is to be provided and the arrangements are to allow easy access for routine maintenance.

4.11.3 The design of filter and strainer arrangements is to be such that they may not be opened inadvertently when under pressure. This may be achieved by either mechanically preventing the pressurised filter from being opened or by providing pressure gauges which clearly indicate which filter is under pressure. In either case, suitable means for pressure release are to be provided, with drain pipes led to a safe location.

4.11.4 Drip trays are to be fitted under fuel oil appliances which are required to be opened up frequently for cleaning or adjustment and at pipes, pumps, valves and other fittings where there is the possibility of leakage. Alternative arrangements may be acceptable and full details should be submitted for consideration.

4.11.5 Short sounding pipes fitted to fuel oil tanks are to be in accordance with *Pt 15, Ch 2, 11.11 Short sounding pipes 11.11.2*

4.12 Fuel oil service tanks

4.12.1 A fuel oil service tank is a fuel oil tank which contains only the required quality of fuel ready for immediate use.

4.12.2 On service craft required to comply with the *International Convention for the Safety of Life at Sea, 1974*, as amended (SOLAS 74) and on yachts that are 500 gt or more, two fuel oil service tanks, for each type of fuel used on board, necessary for propulsion and generator systems, are to be provided. Each tank is to have a capacity for at least eight hours' operation, at sea, at maximum continuous rating of the propulsion plant and/or generating plant associated with that tank.

4.12.3 The arrangement of fuel oil service tanks is to be such that one tank can continue to supply fuel oil when the other is being cleaned or opened up for repair.

■ Section 5
Low flash point fuels

5.1 General

5.1.1 For craft having fuel oil with a flash point below 43ºC the arrangements for the storage, distribution and utilisation of the fuel oil are to be such that the safety of the craft and persons on board is preserved, having regard to fire and explosion hazards. The arrangements are to comply with *Pt 15, Ch 3, 3 Fuel oil storage*, *Pt 15, Ch 3, 4 Fuel oil systems* and *Pt 15, Ch 3, 5.1 General 5.1.2*.

5.1.2 Tanks for the storage of such fuel oil are to be located outside any machinery space and at a distance of not less than 760 mm inboard from the shell and bottom plating, and from decks and bulkheads.

5.1.3 The spaces in which fuel oil tanks are located are to be mechanically ventilated using exhaust fans providing not less than six air changes per hour. The fans are to be such as to avoid the possibility of ignition of flammable gas air mixtures. Suitable wire mesh guards are to be fitted over inlet and outlet ventilation openings. The outlets for such exhausts are to discharge to a safe position.

5.1.4 A fixed vapour detection system is to be installed in each space through which fuel oil lines pass, with alarms provided at a continuously manned control station.

5.1.5 Safe and efficient means of ascertaining the amount of fuel oil contained in any tank is to be provided. Gauge glasses are not to be used. Other means of ascertaining the amount of fuel oil contained in any tank may be permitted if such means do not require penetration below the top of the tank, and providing their failure or overfilling of the tanks will not permit the release of fuel oil.

5.1.6 Vessel to shore fuel oil connections are to be of closed type and suitably grounded during bunkering operations.

5.1.7 Air pipes shall discharge to a safe position and terminate with flame arresters in accordance with *MSC/Circular.677 – Revised Standards for the Design, Testing and Locating of Devices to Prevent the Passage of Flame into Cargo Tanks in Tankers – (Adopted on 30 December 1994)1 Amended by MSC/Circ.1009*.

■ Section 6
Lubricating/hydraulic oil systems

6.1 Lubricating oil arrangements

6.1.1 The arrangements for the storage, distribution and utilisation of oil used in pressure lubrication systems in machinery spaces and, whenever practicable, in auxiliary machinery spaces are to comply with the provisions of *Pt 15, Ch 3, 3.2 Fuel oil storage arrangements* (except 3.2.2), *Pt 15, Ch 3, 3.4 Unattended machinery*, *Pt 15, Ch 3, 4.9 Valves on deep tanks and their control arrangements*, *Pt 15, Ch 3, 4.11 Precautions against fire 4.11.1*, *Pt 15, Ch 3, 4.11 Precautions against fire 4.11.2* and *Pt 15, Ch 3, 4.11 Precautions against fire 4.11.3*.

6.1.2 Tanks containing lubricating oil located within major fire hazard areas are to be of steel or other equivalent material.

6.1.3 For craft not required to comply with the HSC Code, the requirements for remote operation on valves on deep tank suction pipes may be waived where the valves are closed during normal operation.

6.1.4 Remotely operated valves on lubricating oil deep tank suctions should not be of the quick-closing type where inadvertent use would endanger the safe operation of the main propulsion and essential auxiliary machinery.

6.1.5 Where the lubricating oil for main propelling engines is circulated under pressure, provision is to be made for the efficient filtration of the oil. The filters are to be capable of being cleaned without stopping the engine or reducing supply of filtered oil to the engine. Proposals for an automatic by-pass for emergency purposes in high speed engines are to be submitted for consideration.

6.1.6 In addition, yachts and service craft of 24 m or greater in length are to comply with the requirements of *Pt 15, Ch 3, 4.5 Control of pumps* .

6.2 Arrangements for hydraulic and flammable oils

6.2.1 The requirements of this Section are applicable to flammable oils employed under pressure in power transmission, control, actuating and heating systems, and hydraulic media in systems which are providing essential services.

6.2.2 The arrangements for storage, distribution and utilisation of hydraulic and flammable oils employed in the systems defined in this sub-Section are to comply with the provisions of *Pt 15, Ch 3, 6.1 Lubricating oil arrangements*.

6.3 Lubricating/hydraulic oil standby arrangements

6.3.1 Where lubricating oil for the main engine(s) is circulated under pressure, a standby lubricating oil pump is to be provided where the following conditions apply:

(a) The lubricating oil pump is independently driven and the total output of the main engine(s) exceeds 500 kW.
(b) One main engine with its own lubricating oil pump is fitted and the output of the engine exceeds 500 kW.
(c) More than one engine each with its own lubricating oil pump is fitted and the output of each engine exceeds 500 kW.

6.3.2 The standby pump is to be of sufficient capacity to maintain the supply of oil for normal conditions with any one pump out of action. The pump is to be fitted and connected ready for immediate use. Where the conditions referred to in *Pt 15, Ch 3, 6.3 Lubricating/hydraulic oil standby arrangements 6.3.1.(c)* apply and the craft cannot navigate safely with one of the main engines out of action, the main engines are to be provided with a standby pump. In all cases, satisfactory lubrication of the engines is to be ensured while starting and manoeuvring.

6.3.3 Where the conditions referred to in *Pt 15, Ch 3, 6.3 Lubricating/hydraulic oil standby arrangements 6.3.1.(c)* apply and the craft can navigate safely with one of the main engines out of action, standby pumps are not required.

6.3.4 Similar provisions to those of *Pt 15, Ch 3, 6.3 Lubricating/hydraulic oil standby arrangements 6.3.1* to *Pt 15, Ch 3, 6.3 Lubricating/hydraulic oil standby arrangements 6.3.3* are to be made where separate lubricating/hydraulic oil systems are employed for piston cooling, reduction gears, oil operated couplings, controllable pitch propellers and steering systems etc, unless approved alternative arrangements are provided.

6.3.5 Independently driven pumps of rotary type are to be fitted with a non-return valve on the discharge side of the pump.

6.4 Lubricating oil contamination

6.4.1 The materials used in the storage and distribution of lubricating oil are to be selected such that they do not introduce or modify the properties of the oil. The use of cadmium or zinc in lubricating oil systems where they may come into contact with the oil is not permitted.

6.4.2 Arrangements are to be made for each forced lubrication system, renovation system, ready to use tank(s) and their associated rundown lines to drain tanks to be flushed after system installation and prior to running of machinery. The flushing arrangements are to be in accordance with the equipment manufacturer's procedures and recommendations.

6.4.3 The design and construction of engine and gear box piping arrangements are to prevent as far as practicable, contamination of engine lubricating oil systems by leakage of cooling water or from bilge water where engines or gearboxes are partly installed below the lower platform.

6.4.4 Where a lubricating oil filling pipe and cap are provided for engines and other machinery, provision is to be made for the topping up oil to pass through a gauze strainer. The caps are to be capable of being secured in the closed position.

6.4.5 Sampling points are to be provided that enable samples of lubricating oil to be taken in a safe manner. The sampling arrangements are to have the capability to provide samples when machinery is running and are to be provided with valves and cocks of the self-closing type and located in positions as far removed as possible from any heated surface or electrical equipment.

■ *Section 7*
Engine cooling water systems

7.1 General

7.1.1 The cooling arrangements provided are to be adequate to maintain all lubricating and hydraulic fluid temperatures within the manufacturer's recommended limits.

7.2 Main supply

7.2.1 Provision is to be made for an adequate supply of cooling water to the main propelling machinery and essential auxiliary engines, also to the lubricating oil and fresh water coolers and air coolers for electric propelling machinery, where these coolers are fitted. The cooling water pump(s) may be worked from the engines or be driven independently.

7.3 Standby supply

7.3.1 Provision is also to be made for a separate supply of cooling water from a suitable independent pump of adequate capacity.

7.3.2 The following arrangements are acceptable depending on the purpose for which the cooling water is intended:

(a) Where only one main engine is fitted, the standby pump is to be connected ready for immediate use.
(b) Where more than one main engine is fitted, each with its own pump and the craft cannot navigate safely with one of the main engines out of action, the main engines are to be provided with a standby pump as detailed in *Pt 15, Ch 3, 7.3 Standby supply 7.3.2*.
(c) Where more than one main engine is fitted, each with its own pump and the craft can navigate safely with one of the main engines out of action, standby pumps are not required.
(d) Where fresh water cooling is employed for main and/or auxiliary engines, a standby fresh water pump need not be fitted if there are suitable emergency connections from a salt water system.
(e) Where each auxiliary engine is fitted with a cooling water pump, standby means of cooling need not be provided. Where, however, a group auxiliary engine is supplied with cooling water from a common system, a standby cooling water pump is to be provided for this system.

This pump is to be connected ready for immediate use and may be a suitable general service pump.

7.4 Selection of standby pumps

7.4.1 When selecting a pump for standby purposes, consideration is to be given to the maximum pressure which it can develop if the overboard discharge valve is partly or fully closed. Where necessary, water boxes etc. are to be protected against inadvertent over-pressure by an approved device.

7.5 Relief valves on main cooling water pumps

7.5.1 Where cooling water pumps can develop a pressure head greater than the design pressure of the system, they are to be provided with relief valves on the pump discharge to effectively limit the pump discharge pressure to the design pressure of the system.

7.6 Sea inlets

7.6.1 Not less than two sea inlets are to be provided for the pumps supplying the sea water cooling system, one for the main pump and one for the standby pump. Alternatively, the sea inlets may be connected to a suction line available to main and standby pumps.

7.6.2 Where standby pumps are not provided (*see Pt 15, Ch 3, 7.3 Standby supply 7.3.2.(c)* and *Pt 15, Ch 3, 7.3 Standby supply 7.3.2.(e)*), the main pump is to be connected to both sea inlets.

7.6.3 The auxiliary cooling water sea inlets are to be located one on each side of the craft.

7.7 Strainers

7.7.1 Where sea water is used for the direct cooling of the main engines and essential auxiliary engines, the cooling water suction pipes are to be provided with strainers which can be cleaned without interruption to the cooling water supply.

Section 8
Low pressure compressed air systems

8.1 General

8.1.1 The requirements of this Section are applicable to low pressure (LP) compressed air systems intended for essential pneumatic control and instrumentation purposes.

8.1.2 Compressed air systems used for diesel engine starting are to comply with the requirements of *Pt 10, Ch 1, 8.5 Starting air pipe systems and safety fittings* and *Pt 10, Ch 1, 9 Starting arrangements*.

8.2 Compressors and reducing valves/stations

8.2.1 Where LP air is not derived from the starting air system, at least two LP air compressors are to be provided. The output of any one compressor is to match the total demand of all essential users. The system is to be arranged for auto-start of the compressors.

8.2.2 If only one LP air compressor is to be provided, a cross-connection to the starting air system is to be made via a reducing valve/cross-connection station.

8.2.3 Where LP air is derived only from the starting air system, each starting air compressor is to have sufficient capability of supplying the total demand on the LP air system.

8.3 Air receivers

8.3.1 The LP air system and any associated air receivers are to be configured to provide sufficient stored energy to supply LP compressed air without the pressure in the system falling below a level that is insufficient for the operation of all essential users. *See also Pt 16, Ch 1, 2.5 Control systems 2.5.10*.

8.3.2 All air receivers are to comply with the requirements of *Pt 15, Ch 4 Pressure Plant* as applicable.

8.3.3 Stop valves on air receivers are to permit slow opening to avoid sudden pressure rises in the piping system.

8.4 Distribution system

8.4.1 Drain pots with drain valves are to be provided throughout the distribution system at all low points.

8.4.2 Pipelines that are situated on the low pressure side of reducing valves/stations and that are not designed to withstand the full pressure of the source supply, are to be provided with pressure gauges and with relief valves having sufficient capacity to protect the piping against excessive pressure.

8.4.3 In-line filters capable of being cleaned/changed without interrupting the flow of filtered air are to be fitted in the system.

8.5 Pneumatic remote control valves

8.5.1 Where valves, which are required by the Rules to be capable of being closed from outside a machinery space in the event of a fire, have pneumatic closing arrangements, the arrangements are to comply with *Pt 15, Ch 3, 8.5 Pneumatic remote control valves 8.5.2*.

8.5.2 A dedicated air receiver is to be fitted to supply compressed air to the valves. This air receiver is to be located outside the machinery space.

8.5.3 The air receiver is to be maintained fully charged from the main LP air system via a non-return valve located at the air receiver inlet which is to be locked in the open position.

8.5.4 In the case of passenger craft, a permanently attached hand-operated compressor capable of charging the air receiver is to be provided in the space in which the air receiver is located.

8.5.5 The capacity of the air receiver is to be sufficient to operate all valves and any other essential supplies such as ventilation flaps without replenishment.

8.5.6 Where valves, which are required by the Rules to be capable of being operated in the event of a flooding, are pneumatically operated, the arrangements are to comply with *Pt 15, Ch 3, 8.5 Pneumatic remote control valves 8.5.7*.

8.5.7 A compressor is to be fitted to supply compressed air to the valves. This compressor is to be accessible and operable in the flooding condition. Where valves are required by the Rules to be operable from above the bulkhead deck, the compressor is to be located above the bulkhead deck. Consideration shall be given to alternative arrangements which are equivalent to those required by the Rules.

8.6 Control arrangements

8.6.1 The control, alarm and monitoring systems are to comply with *Pt 16, Ch 1 Control Engineering Systems*.

■ *Section 9*
Miscellaneous Machinery

9.1 General

9.1.1 Alarms and safeguards are indicated in *Table 3.9.1 Miscellaneous machinery: Alarms and safeguards*.

Table 3.9.1 Miscellaneous machinery: Alarms and safeguards

Item	Alarm	Note
Coolant tanks level	Low	-
Sludge tanks level	High	-
Feed water tanks level	Low	Service tank only
Hydraulic control system pressure	Low	-
Pneumatic control system pressure	Low	-
Exhaust gas temperature after water injection	High	*See Pt 10, Ch 1, 8.3 Exhaust systems 8.3.7*

■ *Section 10*
Special requirements for multi-hull craft

10.1 General

10.1.1 The requirements of *Pt 15, Ch 3, 1 Application* to *Pt 15, Ch 3, 8 Low pressure compressed air systems* are generally applicable to multi-hull craft except where these are modified by the requirements of this Section.

10.1.2 Where the machinery piping arrangements in each hull of a multi-hull craft are separate and the craft cannot navigate safely with the main propulsion machinery in one hull out of action, the machinery piping and standby requirements are to be as detailed in *Pt 15, Ch 3, 4.2 Booster pumps 4.2.1*, *Pt 15, Ch 3, 6.3 Lubricating/hydraulic oil standby arrangements 6.3.1* or *Pt 15, Ch 3, 6.3 Lubricating/hydraulic oil standby arrangements 6.3.1.(b)*, and *Pt 15, Ch 3, 7.3 Standby supply 7.3.2*, i.e. the requirements for a single-engined mono-hull craft apply to the machinery in each hull.

10.1.3 Where a multi-hull craft can navigate safely with the main propulsion machinery in one hull out of action, standby pumps need not be provided.

Section 11
Requirements for Passenger (A) Craft

11.1 General

11.1.1 The requirements of *Pt 15, Ch 3, 1 Application* to *Pt 15, Ch 3, 10 Special requirements for multi-hull craft* apply except that the standby machinery arrangements detailed in Sections *Pt 15, Ch 3, 6 Lubricating/hydraulic oil systems* and *Pt 15, Ch 3, 7 Engine cooling water systems* are not required.

Section 12
Requirements for small craft which are not required to comply with the HSC Code

12.1 General

12.1.1 The requirements of this Section replace Sections *Pt 15, Ch 3, 3.2 Fuel oil storage arrangements* to *Pt 15, Ch 3, 3.4 Unattended machinery* and *Pt 15, Ch 3, 4 Fuel oil systems*, *Pt 15, Ch 3, 5 Low flash point fuels*, *Pt 15, Ch 3, 6 Lubricating/ hydraulic oil systems* and *Pt 15, Ch 3, 7 Engine cooling water systems* of this Chapter, *see also Pt 15, Ch 1, 15 Requirements for small craft which are not required to comply with the HSC Code*.

12.2 Fuel oil system

12.2.1 Where a power driven fuel oil transfer pump is fitted, it is to be capable of being stopped from a position outside the space which will always be accessible in the event of fire occurring in the compartment in which the pump is situated, as well as from the compartment itself.

12.2.2 Where a power driven pump is necessary for transferring fuel oil, a standby pump is to be provided and connected ready for use.

12.2.3 Where a fuel oil booster pump is fitted, a standby pump is to be provided. The standby pump is to be connected ready for immediate use.

12.3 Separate fuel oil tanks

12.3.1 Except for very small tanks separate fuel oil tanks are to be not less than 3 mm in thickness. The seams are to be welded or brazed. Steel tanks are to be protected from corrosion.

12.3.2 Before installation, all tanks are to be tested by a head of water equal to the maximum to which the tanks may be subjected, but not less than 2,5 m above the crown of the tank.

12.3.3 Separate fuel oil tanks are to be securely fixed in position, and located as remote as practicable from exhaust manifolds and exhaust pipes or other hot surfaces and not above any electrical apparatus. Where this cannot be avoided, a drip tray is to be fitted under the tank and extended sufficiently to catch any drips from fittings attached to the tank.

12.3.4 Fuel oil tanks are not to be fitted above or adjacent to oil fired heaters, cooking stoves, equipment using naked flames or electrical equipment unless this is suitably constructed or enclosed.

12.4 Fuel oil filling

12.4.1 The filling pipe is to be of metallic construction and is to be a permanent fixture led from the deck and secured to the tank by an approved connection. A screwed cap and name plate inscribed 'Fuel Oil' is to be provided at the filling point.

12.4.2 Flexible hoses are not permitted as filling pipes. In composite craft short lengths may be employed at the deck connection to accommodate any movement between the tank and the deck fitting.

12.5 Fuel oil supply

12.5.1 Provision is to be made for efficient filtration of the fuel oil supply to the engine.

12.6 Fuel oil valves and cocks

12.6.1 Outlet valves or cocks are to be fitted to all deep tanks. The valves are to be fitted directly to the tank plating and are to be capable of being closed locally and from positions which will always be readily accessible in the event of fire.

12.6.2 Valve covers are to be so constructed that they will not become slack when the valves are operated.

12.6.3 Heat sensitive materials are not to be used in the construction of valves and cocks.

12.6.4 Where drain cocks or valves are fitted to fuel oil tanks they are to be of the self-closing type and suitable provision is to be made for collecting the oil discharge.

12.7 Flexible hoses for fuel oil systems

12.7.1 Where necessary, flexible pipes of approved type may be used as short joining lengths to the engine.

12.8 Pipe joints for fuel oil systems

12.8.1 Where flanged joints are used the jointing material is to be impervious to oil. Cone type joints and approved types of compression fittings may be permitted for pipes having a bore not exceeding 40 mm.

12.8.2 Soft solder is not to be used for attaching pipe fittings.

12.9 Engine cooling system

12.9.1 Where sea water is used for the direct cooling of the engine, an efficient strainer which can be cleared from inside the craft is to be fitted between the sea inlet valve and the pump.

12.9.2 Means are to be provided for cleaning the strainer without interruption to the cooling water supply, where necessary.

12.9.3 Means are to be provided for indicating the temperature of the engine cooling media.

12.9.4 Alarms for the engine cooling water system are to be provided in accordance with *Pt 10 Prime Movers*.

12.9.5 A standby cooling water pump is to be provided. The standby pump is to be connected ready for immediate use.

12.10 Lubricating oil system

12.10.1 Where the lubricating oil for main propelling engines is circulated under pressure, provision is to be made for the efficient filtration of the oil.

12.10.2 Where necessary, flexible pipes of approved type may be used as short joining lengths to the engine.

12.10.3 In general, joints are to be of the flanged type with jointing materials which are impervious to oil. Cone type joints and approved types of compression fittings may be permitted for pipes having a bore not exceeding 40 mm.

12.10.4 Soft solder is not to be used for attaching pipe fittings.

12.10.5 Means are to be provided for indicating the lubricating oil pressure.

12.10.6 Alarms for the lubricating oil systems are to be provided in accordance with *Pt 10 Prime Movers*.

12.10.7 Where the output of the main engine exceeds 500 kW, a standby lubricating oil pump is to be provided. The standby pump is to be connected ready for immediate use.

12.11 Multi-engined craft

12.11.1 This Section is applicable to craft that have multi-engine installations for propulsion purposes.

12.11.2 Where each main engine has its own fuel oil booster pump, lubricating oil and cooling water pump and the craft can navigate and manoeuvre safely under all conditions of service with one of the main engines out of action, the following are not required:

(a) Standby fuel oil transfer pump stipulated in *Pt 15, Ch 3, 12.2 Fuel oil system 12.2.2*.
(b) Standby fuel oil booster pump stipulated in *Pt 15, Ch 3, 12.2 Fuel oil system 12.2.3*.
(c) Standby cooling water pump stipulated in *Pt 15, Ch 3, 12.9 Engine cooling system 12.9.5*.
(d) Standby lubricating oil pump stipulated in *Pt 15, Ch 3, 12.10 Lubricating oil system 12.10.7*.

12.12 Craft having restricted services G1 to G2A

12.12.1 If the craft has a service area restriction notation **G1** to **G2A**, the following are not required:

(a) Standby fuel oil transfer pump stipulated in *Pt 15, Ch 3, 12.2 Fuel oil system 12.2.2*.
(b) Standby fuel oil booster pump stipulated in *Pt 15, Ch 3, 12.2 Fuel oil system 12.2.3*.
(c) Standby cooling water pump stipulated in *Pt 15, Ch 3, 12.9 Engine cooling system 12.9.5*.
(d) Standby lubricating oil pump stipulated in *Pt 15, Ch 3, 12.10 Lubricating oil system 12.10.7*.
(e) Standby pneumatic air compressor stipulated in *Pt 15, Ch 3, 8.2 Compressors and reducing valves/stations 8.2.1*.

■ *Section 13*
Ballast water treatment system and installation

13.1 General

13.1.1 The requirements given in the *Rules and Regulations for the Classification of Ships, July 2021*, *Pt 5, Ch 25 Ballast Water Treatment System and Installation* are to be complied with, as applicable.

■ *Section 14*
Emissions abatement plant

14.1 General

14.1.1 Where any aspect of the design or construction of an emissions abatement plant is not covered by this Section, the relevant requirements of the *Rules and Regulations for the Classification of Ships, July 2021* or the *Rules and Regulations for the Classification of Naval Ships, January 2021, incorporating Notice No. 1, 2, 3 & 4* are to be applied as considered necessary as described in *Pt 1, Ch 2, 2.1 Applicable craft types 2.1.6*.

14.1.2 Materials used for emissions abatement system piping and associated chemical storage tanks are to be constructed of corrosion-resistant material which is to be suitable for the expected operating temperatures, as well as the corrosive properties of any chemicals associated with the process. Where it is proposed to use corrosion-resistant coating or lining, this is to be subject to special approval. The elasticity of such coatings and lining is not to be less than that of the supporting boundary material.

14.2 Chemical Storage

14.2.1 Substance and effluent tanks are to be protected from mechanical damage. This may be achieved either by installation in spaces where there are no cargo or vehicle movements and where no heavy lifting operations are expected; or by mechanical protection, if installed in spaces where such operations may take place.

14.2.2 The location of substance and effluent tanks within the ship’s hull are to comply with *Ship Survival Capability and Location of Cargo Tanks* and *Cargo Containment* of the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquid Chemicals in Bulk, July 2021*. Alternative proposals demonstrating equivalent or increased protection against damage in the event of collision or grounding may be considered.

14.2.3 Where chemical substances are sensitive to variations in temperature, they are to be maintained within their allowable maximum and minimum temperatures. Where necessary, the probable temperature variations during operations and the thermal stress considerations are to be stated. Where it is necessary either to heat or cool chemical storage tanks, the arrangements are to maintain tanks within the specified temperature range under the following conditions:

	Heating systems	Cooling systems
Seawater temperature	0°C	32°C
Air temperature	5°C	45°C

14.2.4 Heating and cooling arrangements which utilise pipe coils or ducts for circulating a heating or cooling medium within the chemical storage tank, or a heat exchanger through which the chemical and a heating or cooling medium is circulated, are to use heating or cooling media which is suitable for use with the specific chemical. Consideration is to be given to the surface temperature of heating coils or ducts to avoid dangerous reactions from localised overheating or overcooling of chemicals. Heating or cooling systems are to be provided with valves to isolate the system and to allow manual regulation of flow, along with a means for measuring the chemical temperature.

14.2.5 Tank venting systems are to meet the requirements of *Pt 15, Ch 2, 11 Air, overflow and sounding pipes*, and are to minimise the possibility of chemical vapour accumulating about the decks, entering accommodation, service and machinery spaces, and control stations, and, in the case of flammable vapours, entering or collecting in spaces or areas containing sources of ignition. Tank venting systems are to be arranged to prevent entrance of water into the chemical tanks. The venting systems shall be connected to the top of each chemical tank and, as far as is reasonably practicable, are to be self-draining back to the chemical tanks under all normal operational conditions of list and trim.

14.2.6 Chemical transfer and control arrangements are to be provided with a stop-valve capable of being manually operated on each tank filling and discharge line, which where practicable is to be attached directly to the tank plating. Additionally, a stop valve at each chemical-hose loading connection. Where there is a possibility of gravity discharge of the tank contents in the event of a pipe or valve failure then discharge valve is to of the quick closing type.

14.2.7 Spillage and leakage from chemical tanks is to be contained. This may be achieved by using containment bunds, or double skin tanks or by installing the tank in a dedicated space. The arrangements are to consider the likely sources of spillage or leakage and the anticipated volume released before the spillage or leakage can be stopped.

14.2.8 Chemical tanks are to be arranged such that any residues and slops can be pumped out, drained, or otherwise removed from the tank without exposing personnel to these residues and slops.

14.2.9 Portable chemical tanks are subject to special consideration and, where permitted, are to meet the requirements of *Pt 15, Ch 3, 14.1 General 14.1.2* and *Pt 15, Ch 3, 14.2 Chemical Storage 14.2.1* to *Pt 15, Ch 3, 14.2 Chemical Storage 14.2.8*.

■ *Section 1*
General requirements

1.1 Application

1.1.1 The requirements of this Chapter are applicable to fusion welded pressure vessels and their mountings and fittings, where plans have to be submitted in accordance with *Pt 15, Ch 4, 1.2 Details to be submitted*.

1.1.2 Seamless pressure vessels are to be manufactured in accordance with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials, July 2021* (hereinafter referred to as the Rules for Materials) where applicable.

1.1.3 Steam raising plant and associated pressure vessels should be designed and constructed in accordance with *Pt 5, Ch 10 Steam Raising Plant and Associated Pressure Vessels* of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships).

1.2 Details to be submitted

1.2.1 Plans of pressure vessels are to be submitted in triplicate for consideration where all the conditions in (a) or (b) are satisfied:

(a) The vessel contains vapours or gases, e.g. air receivers, hydrophore or similar vessels and gaseous CO_2 vessels for fire-fighting, and

$pV > 60$
$p > 0,1$
$V > 100$

V = volume (litres) of gas or vapour space

p = design pressure (MPa)

(b) The vessel contains liquefied gases, or flammable liquids, and

$p > 0,7$
$V > 100$

V = volume (litres)

p = design pressure (MPa).

1.3 Materials

1.3.1 Materials used in the construction of Class 1, 2/1 and 2/2 pressure vessels are to be manufactured, tested and certified in accordance with the requirements of the Rules for Materials. Materials used in the construction of Class 3 pressure vessels may be in accordance with the requirements of an acceptable National or International Standard. The manufacturer's certificate will be accepted in lieu of LR's material certificate for such materials.

1.3.2 The specified minimum tensile strength of carbon and carbon-manganese steel plates, pipes, forgings and castings is to be within the following general limits:

(a) For seamless and Class 1 and Class 2/1 fusion welded pressure vessels:

340 to 520 N/mm^2.

(b) For Class 2/2 and where required Class 3 fusion welded pressure vessels:

340 to 430 N/mm^2.

1.3.3 Where it is proposed to use materials other than those specified in the *Rules for the Manufacture, Testing and Certification of Materials, July 2021*, details of the chemical compositions, heat treatment and mechanical properties are to be submitted for approval. In such cases, the values of the mechanical properties used for deriving the allowable stress are to be subject to agreement by Lloyd's Register (hereinafter referred to as 'LR').

1.4 Classification of fusion welded pressure vessels

1.4.1 Fusion welded pressure vessels are graded as Class 1 where the shell thickness exceeds 38 mm.

1.4.2 Fusion welded pressure vessels are graded as Class 2/1 and Class 2/2 if they comply with the following conditions:

(a) where the design pressure exceeds 1,72 MPa, or
(b) where the metal temperature exceeds 150°C, or
(c) where the design pressure, in MPa, multiplied by the actual thickness of the shell, in mm exceeds 15,7, or
(d) where the shell thickness does not exceed 38 mm.

1.4.3 For Rule purposes, Class 3 pressure vessels are to have a maximum shell thickness of 16 mm, and are pressure vessels not included in Classes 1, 2/1 or 2/2.

1.5 Design pressure

1.5.1 The design pressure is the maximum permissible working pressure and is to be not less than the highest set pressure of any safety valve.

1.6 Metal temperature

1.6.1 The metal temperature, T, used to evaluate the allowable stress, σ, is to be taken as the actual mean wall metal temperature expected under operating conditions for the pressure part concerned, and is to be stated by the manufacturer when plans of the pressure parts are submitted for consideration.

1.6.2 For fusion welded pressure vessels the minimum design temperature, T, is not to be less than 50^{o}C.

1.7 Definition of symbols

1.7.1 The symbols used in the various formulae in *Pt 15, Ch 4, 2 Cylindrical shells subject to internal pressure*, unless otherwise stated, are defined as follows and are applicable to the specific part of the pressure vessel under consideration:

p = design pressure, in MPa, *see Pt 15, Ch 4, 1.5 Design pressure*

r_i = inside knuckle radius, in mm

r_o = outside knuckle radius, in mm

t = minimum thickness, in mm

D_i = inside diameter, in mm

D_o = outside diameter, in mm

J = joint factor applicable to welded seams

R_i = inside radius, in mm

R_o = outside radius, in mm

T = design temperature, °C

σ = allowable stress in N/mm^2, *see Pt 15, Ch 4, 1.8 Allowable stress*.

1.7.2 Where reference is made to calculated or actual plate thickness for the derivation of other values, these thicknesses are to be minus the standard Rule corrosion allowance of 0,75 mm, if not so stated.

1.8 Allowable stress

1.8.1 The term `allowable stress', σ, is the stress to be used in the formulae for the calculation of scantlings of pressure parts.

1.8.2 The allowable stress, σ, is to be the lowest of the following values:

$$\sigma = \frac{E_t}{1,5}$$

$$\sigma = \frac{R_{20}}{2,7}$$

$$\sigma = \frac{S_R}{1,5}$$

where

E_t = specified minimum lower yield stress or 0,2 per cent proof stress at temperature, *T*, for carbon and carbon-manganese steels. In the case of austenitic steels, the 1,0 per cent proof stress at temperature, *T*, is to be used.

R_{20} = specified minimum tensile strength at room temperature

S_R = average stress to produce rupture in 100 000 hours at temperature, *T*

T = metal temperature, *see Pt 15, Ch 4, 1.6 Metal temperature*.

1.8.3 The allowable stress for steel castings is to be taken as 80 per cent of the value determined by the method indicated in *Pt 15, Ch 4, 1.8 Allowable stress 1.8.2*, using the appropriate values for cast steel.

1.8.4 Where steels castings, which have been tested in accordance with *Rules for the Manufacture, Testing and Certification of Materials, July 2021*, are also subjected to non-destructive tests, consideration will be given to increasing the allowable stress using a factor up to 90 per cent in lieu of the 80 per cent referred to in *Pt 15, Ch 4, 1.8 Allowable stress 1.8.3*. Particulars of the non-destructive test proposals are to be submitted for consideration.

1.9 Joint factors

1.9.1 The following joint factors are to be used in the equations in *Pt 15, Ch 4, 2 Cylindrical shells subject to internal pressure*, where applicable. Fusion welded pressure parts are to be made in accordance with *Pt 15, Ch 4, 8 Requirements for fusion welded pressure vessels*.

Class of pressure vessel	Joint factor
Class 1	1,0
Class 2/1	0,85

Class 2/2	0,75
Class 3	0,6

1.9.2 The longitudinal joints for all Classes of vessels are to be butt joints. Circumferential joints for Class 1 vessels and all classes of vessel for the production and storage of steam are also to be butt welds. Circumferential joints for Class 2/1, 2/2 and 3 vessels should also be butt joints with the following exceptions:

(a) Circumferential joints for Class 2/1, 2/2 and 3 vessels may be of the joggle type provided neither plate at the joints exceeds 16 mm thickness.
(b) Circumferential joints for Class 3 vessels may be of the lap type provided neither plate at the joint exceeds 16 mm thickness nor the internal diameter of the vessel exceeds 610 mm.

For typical acceptable methods of attaching dished ends, *see Figure 4.6.1 Typical methods of attachment of unstayed circular flat end plates*.

1.10 Pressure parts of irregular shape

1.10.1 Where pressure parts are of such irregular shape that it is impracticable to design their scantlings by the application of formulae in this Chapter, the suitability of their construction is to be determined by hydraulic proof test of a prototype or by agreed alternative method.

■ *Section 2* Cylindrical shells subject to internal pressure

2.1 Minimum thickness

2.1.1 Minimum thickness, *t*, of a cylindrical shell is to be determined by the following formula:

$$t = \frac{pR_i}{10\,\sigma\,J - 0,5p} + 0,75 \text{ mm}$$

where

t, *p*, R_i and σ are defined in *Pt 15, Ch 4, 1.7 Definition of symbols*.

J = the joint factor of the longitudinal joints (expressed as a fraction), *see Pt 15, Ch 4, 1.9 Joint factors 1.9.1*. In the case of seamless shells clear of openings, *J* = 1,0

2.1.2 The formula in *Pt 15, Ch 4, 2.1 Minimum thickness 2.1.1* is applicable only where the resulting thickness does not exceed half the internal radius, i.e. where R_o is not greater than 1,5R_i.

2.1.3 For fusion welded pressure vessels, *t*, is to be not less than $3 + \frac{D_i}{1500}$ mm, where D_i is as defined in *Pt 15, Ch 4, 1.7 Definition of symbols*.

2.1.4 The minimum thickness of vessels manufactured of steels with improved corrosion resistance properties will be the subject of special consideration.

2.2 Unreinforced openings

2.2.1 The maximum diameter, *d*, of any unreinforced isolated openings is to be determined by the following formula:

$$d = 8,08\left[D_o t(1 - K)\right]^{1/3} \text{ in mm}$$

The value of K to be used is calculated from the following formula:

$$K = \frac{pD_o}{18,2\,\sigma\,t}$$ but is not to be taken as greater than 0,99

where

p, D_o and σ = are as defined in *Pt 15, Ch 4, 1.7 Definition of symbols*

t = actual thickness of shell, in mm.

2.2.2 For elliptical or oval holes, d, for the purposes of *Pt 15, Ch 4, 2.2 Unreinforced openings 2.2.1*, refers to the major axis when this lies longitudinally or to the mean of the major and minor axes when the minor axis lies longitudinally.

2.2.3 No unreinforced opening is to exceed 200 mm in diameter.

2.2.4 Holes may be considered isolated if the centre distance between two holes on the longitudinal axis of a cylindrical shell is not less than:

$d + 1,1\sqrt{Dt}$ with a minimum 5d

where

d = diameter of openings in shell (mean diameter if dissimilarly sized holes are involved)

D = mean diameter of shell

t = actual thickness of shell

Where the centre distance is less than so derived, the holes are to be fully compensated.

2.3 Reinforced openings

2.3.1 Openings larger than those permitted by *Pt 15, Ch 4, 2.2 Unreinforced openings* are to be compensated in accordance with *Figure 4.2.1 Compensation for welded standpipes or branches in cylindrical shells*. The following symbols are used in Fig. 4.2.1(a) and (b):

t_s = calculated thickness of a shell without joint or opening or corrosion allowance, in mm

t_d = thickness calculated in accordance with *Pt 15, Ch 4, 3.1 Minimum thickness* without corrosion allowance, in mm

t_a = actual thickness of shell plate without corrosion allowance, in mm

t_b = actual thickness of standpipe without minus tolerances and corrosion allowance, in mm

t_r = thickness of added reinforcement, in mm

D_i = internal diameter of cylindrical shell, in mm

d_o = diameter of hole in shell, in mm

L = width of added reinforcement not exceeding D, in mm

C = $\sqrt{d_o t_b}$ in mm

D = $\sqrt{D_i t_a}$ and is not to exceed 0,5d_o, in mm

σ = shell plate allowable stress, N/mm^2

σ_p = standpipe allowable stress, N/mm^2

σ_r = added reinforcement allowable stress, N/mm^2

σ_w = weld metal allowable stress, N/mm^2

Note σ_p, σ_r and σ_w are not to be taken as greater than σ.

2.3.2 For eliptical or oval holes, the dimension on the meridian of the shell is to be used for d_o in *Pt 15, Ch 4, 2.3 Reinforced openings 2.3.1*.

2.3.3 The welds attaching standpipes and reinforcing plates to the shell are to be of sufficient size to transmit the full strength of the reinforcing areas and all other loadings to which they may be subjected.

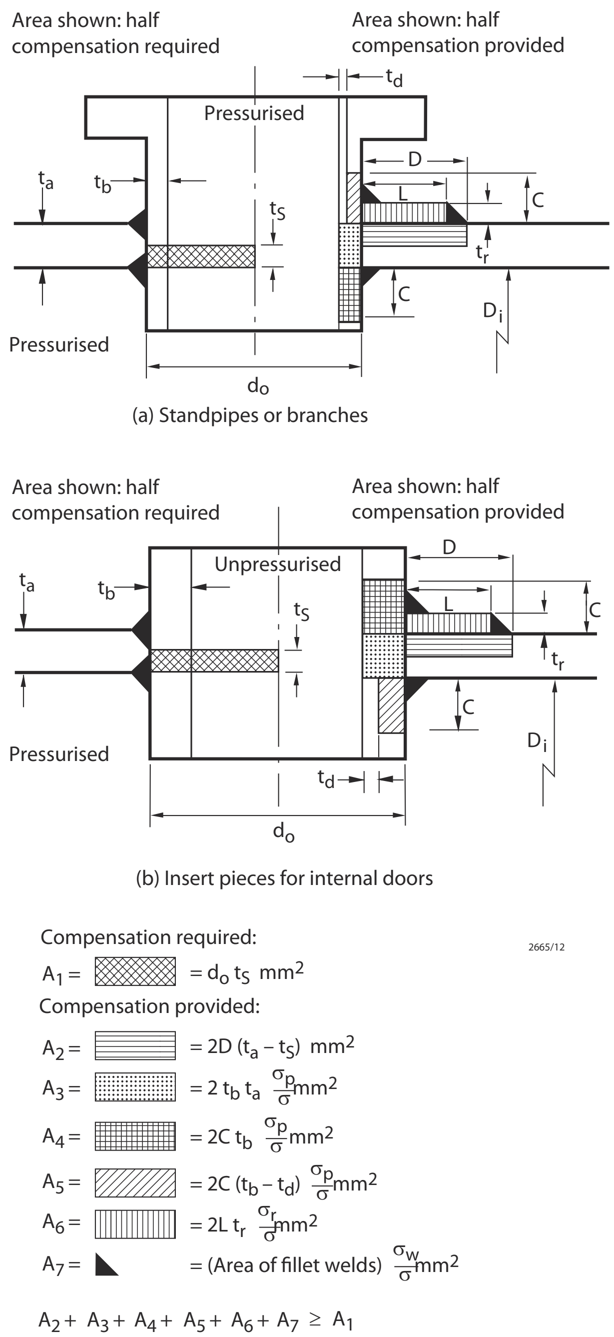


Figure 4.2.1 Compensation for welded standpipes or branches in cylindrical shells

Section 3
Spherical shells subject to internal pressure

3.1 Minimum thickness

3.1.1 The minimum thickness, *t*, of a spherical shell is to be determined by the following formula:

$$t = \frac{pR_i}{20\,\sigma J - 0,5p} + 0,75 \text{ mm}$$

where

= *t*, *p*, R_i, σ and *J* are as defined in *Pt 15, Ch 4, 1.7 Definition of symbols*.

3.1.2 The formula in *Pt 15, Ch 4, 3.1 Minimum thickness 3.1.1* is applicable only where the resulting thickness does not exceed half the internal radius.

3.1.3 Irrespective of the thickness determined by the formula in 3.1.1, *t* is to be not less than $\frac{D_i}{1500} + 3$ mm for other pressure vessels, where D_i is as defined in *Pt 15, Ch 4, 1.7 Definition of symbols*.

3.1.4 The minimum thickness permitted for vessels manufactured in corrosion resistant steels will be the subject of special consideration.

3.1.5 Openings in spherical shells requiring compensation are to comply, in general, with *Pt 15, Ch 4, 2.3 Reinforced openings*, using the calculated and actual thicknesses of the spherical shell as applicable.

Section 4
Dished ends subject to internal pressure

4.1 Minimum thickness

4.1.1 The thickness, *t*, of semi-ellipsoidal and hemispherical unstayed ends, and the knuckle section of torispherical ends, dished from plate, having pressure on the concave side and satisfying the conditions listed below, is to be determined by the following formula:

$$t = \frac{pD_oK}{20\,\sigma J} + 0,75 \text{ mm}$$

where

= *t*, *p*, D_o, σ and *J* are as defined in *Pt 15, Ch 4, 1.7 Definition of symbols*

K = a shape factor, *see Pt 15, Ch 4, 4.2 Shape factors for dished ends* and *Figure 4.4.1 Shape Factor*.

4.1.2 For semi-ellipsoidal ends:

the external height, H ≥ 0,18 D_o

where

D_o = the external diameter of the parallel portion of the end, in mm.

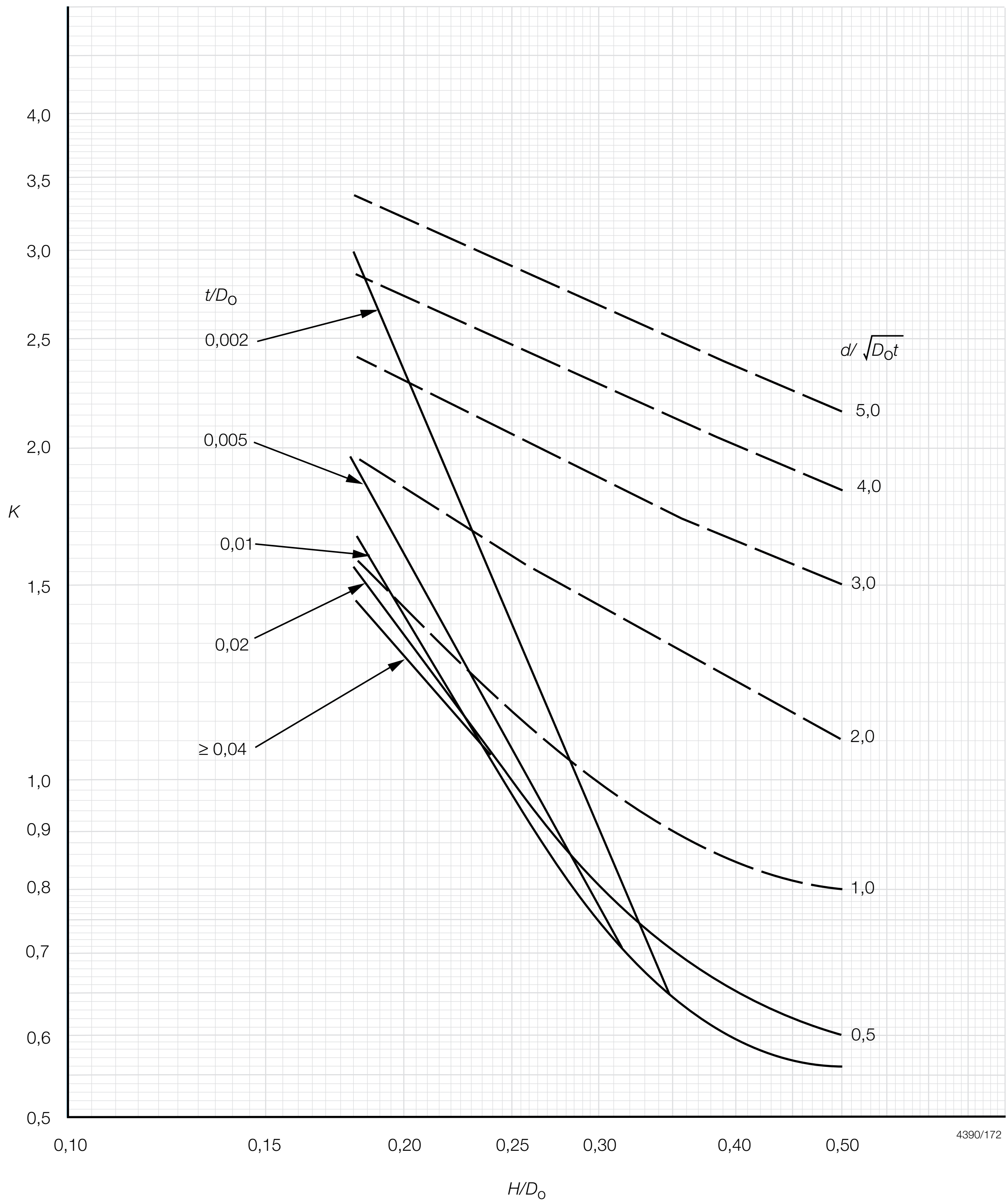


Figure 4.4.1 Shape Factor

4.1.3 For torispherical ends:

- the internal radius, $R_i \leq D_o$
- the internal knuckle radius, $r_i \geq 0{,}1 D_o$

- the internal knuckle radius, $r_{\mathrm{i}} \geq 3t$
- the external height, $H \geq 0{,}18\, D_{\mathrm{o}}$ and is determined as follows:

$$H = R_{\mathrm{o}} - \sqrt{\left(R_{\mathrm{o}} - 0{,}5D_{\mathrm{o}}\right)\left(R_{\mathrm{o}} + 0{,}5D_{\mathrm{o}} - 2r_{\mathrm{o}}\right)}$$

4.1.4 In addition to the formula in *Pt 15, Ch 4, 4.1 Minimum thickness 4.1.1* the thickness, t, of a torispherical head, made from more than one plate, in the crown section is to be not less than that determined by the following formula:

$$t = \frac{pR_{\mathrm{i}}}{20\,\sigma\,J - 0{,}5p} + 0{,}75 \text{ mm}$$

where t, p, R_{i}, σ and J are as defined in *Pt 15, Ch 4, 1.7 Definition of symbols*.

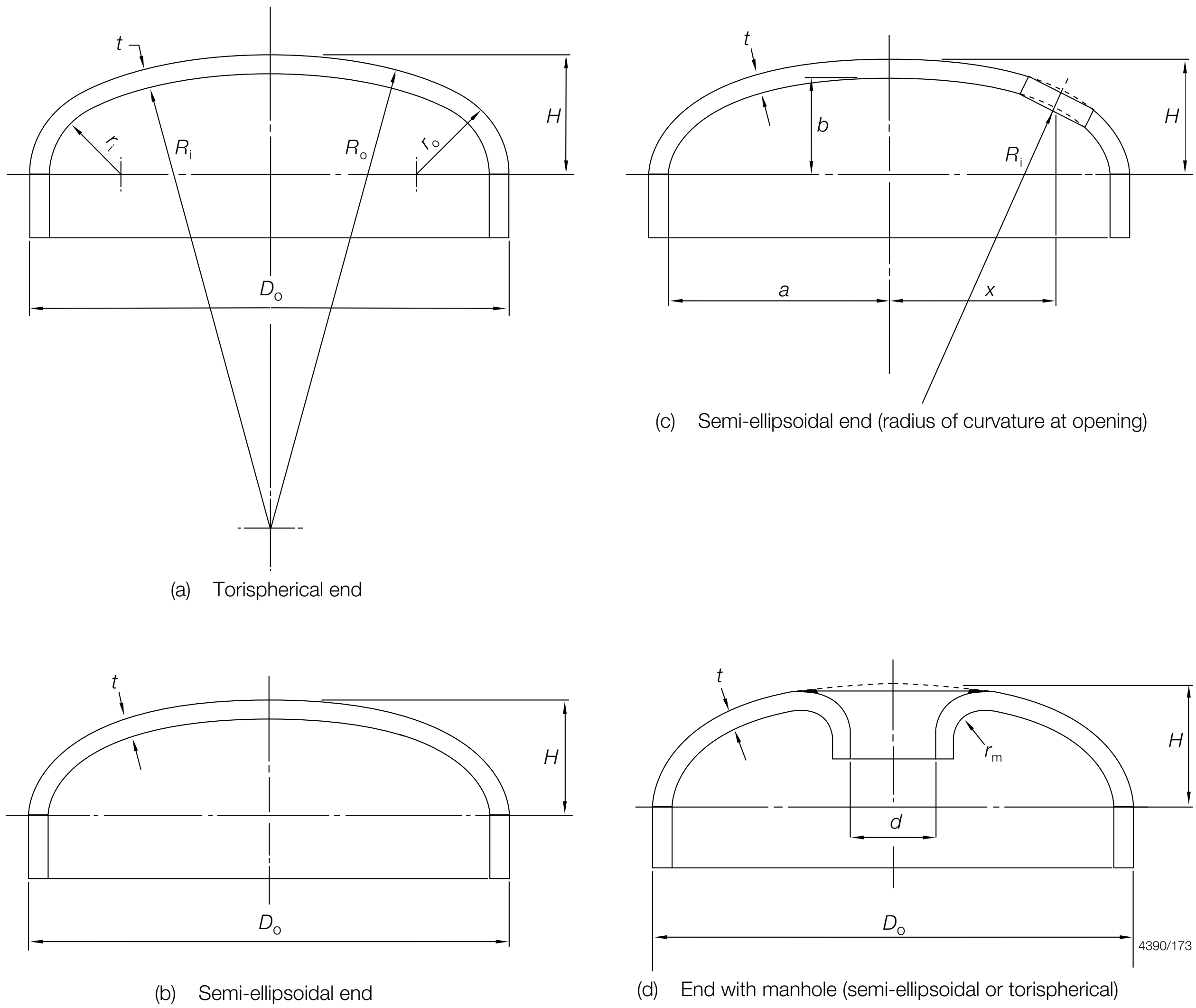


Figure 4.4.2 Typical dished ends

4.1.5 The thickness required by *Pt 15, Ch 4, 4.1 Minimum thickness 4.1.1* for the knuckle section of a torispherical head is to extend past the common tangent point of the knuckle and crown radii into the crown section for a distance not less than $0{,}5\sqrt{R_{\mathrm{i}}t}$ mm, before reducing to the crown thickness permitted by *Pt 15, Ch 4, 4.1 Minimum thickness 4.1.4*,

where

t = the required thickness from *Pt 15, Ch 4, 4.1 Minimum thickness 4.1.1*.

4.1.6 In all cases, H, is to be measured from the commencement of curvature, *see Figure 4.4.2 Typical dished ends*.

4.1.7 For fusion welded pressure vessels the minimum thickness of the head, t, is to be not less than $3 + \frac{D_i}{1500}$ mm where D_i is as defined in *Pt 15, Ch 4, 1.7 Definition of symbols*.

4.1.8 For ends which are butt welded to the shell the thickness of the edge of the flange for connection to the shell is to be not less than the thickness of an unpierced seamless or welded shell, whichever is applicable, of the same diameter and material and determined by *Pt 15, Ch 4, 2.1 Minimum thickness*.

4.2 Shape factors for dished ends

4.2.1 The shape factor, K, to be used in *Pt 15, Ch 4, 4.1 Minimum thickness 4.1.1* is to be obtained from the curves in *Figure 4.4.1 Shape Factor*, and depends on the ratio of height to diameter $\frac{H}{D_o}$.

4.2.2 The lowest curve in the series provides the factor, K, for plain (i.e. unpierced) ends. For lower values of $\frac{H}{D_o}$, K depends upon the ratio of thickness to diameter, $\frac{t}{D_o}$, as well as on the ratio $\frac{H}{D_o}$, and a trial calculation may be necessary to arrive at the correct value of K.

4.3 Dished ends with unreinforced openings

4.3.1 Openings in dished ends may be circular, obround or approximately elliptical.

4.3.2 The upper curves in *Figure 4.4.1 Shape Factor* provide values of K, to be used in *Pt 15, Ch 4, 4.1 Minimum thickness 4.1.1*, for ends with unreinforced openings. The selection of the correct curve depends on the value of $\frac{d}{\sqrt{D_o t}}$ and a trial calculation is necessary to select the correct curve,

where

d = the diameter of the largest opening in the end plate, in mm (in the case of an elliptical opening, the larger axis of the ellipse)

t = minimum thickness, after dishing, in mm

D_o = outside diameter of dished end, in mm

4.3.3 The following requirements must in any case be satisfied:

$$\frac{t}{D_o} \leq 0,1$$

$$\frac{d}{D_o} \leq 0,7$$

4.3.4 From *Figure 4.4.1 Shape Factor* for any selected ratio of $\frac{H}{D_o}$ the curve for unpierced ends gives a value for $\frac{d}{\sqrt{D_o t}}$ as well as for K. Openings giving a value of $\frac{d}{\sqrt{D_o t}}$ not greater than the value so obtained may thus be pierced through an end designed as unpierced without any increase in thickness.

4.4 Flanged openings in dished ends

4.4.1 The requirements in *Pt 15, Ch 4, 4.3 Dished ends with unreinforced openings* apply equally to flanged openings and to unflanged openings cut in the plate of an end. No reduction may be made in end plate thickness on account of flanging.

4.4.2 Where openings are flanged, the radius, r_m of the flanging is to be not less than 25 mm, *see Figure 4.4.2 Typical dished ends*. The thickness of the flanged portion may be less than the calculated thickness.

4.5 Location of unreinforced and flanged openings in dished ends

4.5.1 Unreinforced and flanged openings in dished ends are to be so arranged that the distance from the edge of the hole to the outside edge of the plate and the distance between openings are not less than those shown in *Figure 4.4.3 Limits for reinforcement*.

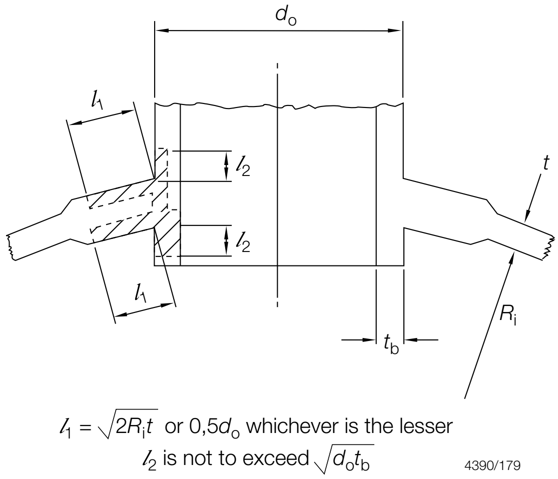


Figure 4.4.3 Limits for reinforcement

4.6 Dished ends with reinforced openings

4.6.1 Where it is desired to use a large opening in a dished end of less thickness than would be required by *Pt 15, Ch 4, 4.3 Dished ends with unreinforced openings*, the end is to be reinforced. This reinforcement may consist of a ring or standpipe welded into the hole, or of reinforcing plates welded to the outside and/or inside of the end in the vicinity of the hole, or a combination of both methods, *see Figure 4.4.4 Opening in dished ends*. Forged reinforcements may be used.

4.6.2 Reinforcing material with the following limits may be taken as effective reinforcement:

(a) The effective width, l_1 of reinforcement is not to exceed $\sqrt{2R_i t}$ or 0,5d_o whichever is the lesser.

(b) The effective length, l_2 of a reinforcing ring is not to exceed $\sqrt{d_o t_b}$

where

R_i = the internal radius of the spherical part of a torispherical end, in mm, or

R_i = internal radius of the meridian of the ellipse at the centre of the opening, of a semi-ellipsoidal end, in mm, and is given by the following formula:

$$= \frac{\left[a^4 - x^2\left(a^2 - b^2\right)\right]^{\frac{3}{2}}}{a^4 b}$$

= where *a*, *b* and *x* are shown in *Figure 4.4.2 Typical dished ends*

d_o = external diameter of ring or standpipe, in mm

l_1 and l_2 are shown in *Figure 4.4.3 Limits for reinforcement*

t_b = actual thickness of ring or standpipe, in mm

4.6.3 The shape factor, *K*, for a dished end having a reinforced opening can be read from *Figure 4.4.1 Shape Factor* using the value obtained from:

$$\frac{d_{o}-\frac{A}{t}}{\sqrt{D_{o}t}}\ \textit{instead of from}\ \frac{d}{\sqrt{D_{o}t}}$$

where

A = the effective cross-sectional area of reinforcement and is to be twice the area shown shaded on *Figure 4.4.3 Limits for reinforcement*.

As in *Pt 15, Ch 4, 4.3 Dished ends with unreinforced openings*, a trial calculation is necessary in order to select the correct curve.

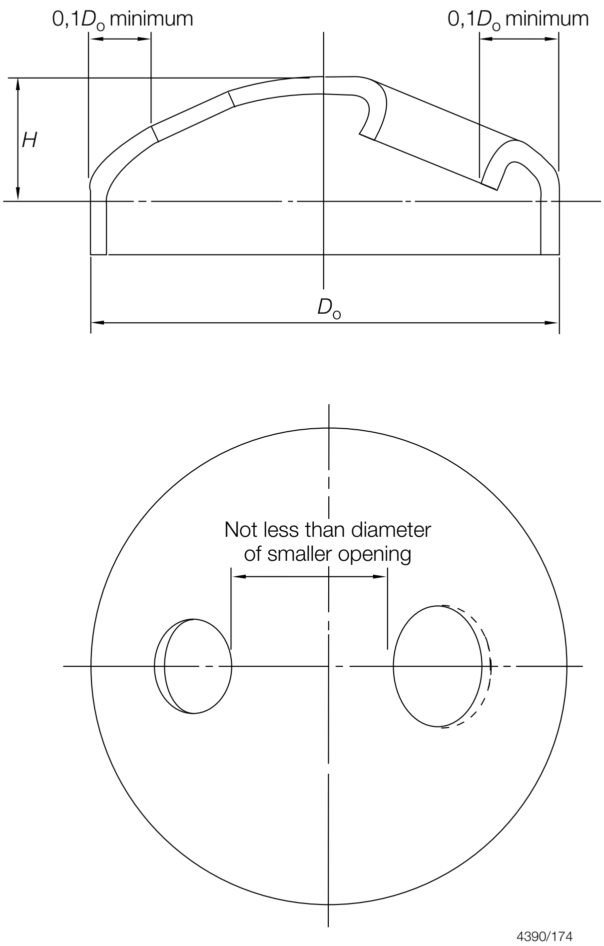


Figure 4.4.4 Opening in dished ends

4.6.4 The area shown in *Figure 4.4.3 Limits for reinforcement* is to be obtained as follows:

- Calculate the cross-sectional area of reinforcement both inside and outside the end plate within the length, l_1, plus the full cross-sectional area of that part of the ring or standpipe which projects inside the end plate up to a distance, l_2, plus the full cross-sectional area of that part of the ring or standpipe which projects outside the internal surface of the end plate up to a distance, l_2, and deduct the sectional area which the ring or standpipe would have if its thickness were as calculated in accordance with *Pt 15, Ch 4, 5.1 Minimum thickness*.

4.6.5 If the material of the ring or the reinforcing plates has an allowable stress value lower than that of the end plate, then the effective cross-sectional area, A, is to be multiplied by the ratio:

$$\frac{\text{Allowable stress of reinforcing plate at design temperature}}{\text{Allowable stress of end plate at design temperature}}$$

4.7 Torispherical dished ends with reinforced openings

4.7.1 If an opening and its reinforcement are positioned entirely within the crown section, the compensation requirements are to be as for a spherical shell, using the crown radius as the spherical shell radius. Otherwise, the requirements of *Pt 15, Ch 4, 4.6 Dished ends with reinforced openings* are to be applied.

■ *Section 5* Standpipes and branches

5.1 Minimum thickness

5.1.1 The minimum wall thickness, *t*, of standpipes and branches is to be not less than the greater of the two values determined by the following formulae, making such additions as may be necessary on account of bending, static loads and vibrations:

$$t = \frac{pD_o}{20\sigma + p} + 0,75 \text{ mm}$$

$$t = 0,015D_o + 3,2 \text{ mm}$$

where t, p, D_o and σ are defined in *Pt 15, Ch 4, 1.7 Definition of symbols*.

If the second formula applies, the thickness need only be maintained for a length, *L*, from the outside surface of the vessel, but need not extend past the first connection, butt weld or flange, where:

$$L = 3,5\sqrt{D_o t} \text{ mm}$$

5.1.2 In no case does the wall thickness need to exceed that of the shell as required by *Pt 15, Ch 4, 2.1 Minimum thickness*, *Pt 15, Ch 4, 3.1 Minimum thickness* or *Pt 15, Ch 4, 4.1 Minimum thickness* as applicable.

■ *Section 6* Unstayed circular flat end plates

6.1 Minimum thickness

6.1.1 Ends attached by welding are to be designed such that the minimum thickness of flat end plates is to be determined by the following formula:

$$t = d_i\sqrt{\frac{pC}{\sigma}} + 0,75 \text{ mm}$$

where

= p and σ are as defined in *Pt 15, Ch 4, 1.7 Definition of symbols*.

t = minimum thickness of end plate, in mm

d_i = internal diameter of circular shell, in mm

C = a constant depending on method of end attachment, *see Figure 4.6.1 Typical methods of attachment of unstayed circular flat end plates*.

(a) For end plates welded as shown in *Figure 4.6.1 Typical methods of attachment of unstayed circular flat end plates*:

C = 0,019 for circular shells.

(b) For end plates welded as shown in *Figure 4.6.1 Typical methods of attachment of unstayed circular flat end plates*:

C = 0,028 for circular shells.

6.1.2 Where flat end plates are bolted to flanges attached to the ends of headers, the flanges and end plates are to be in accordance with recognised pipe flange standards.

6.1.3 Openings in flat plates are to be compensated in accordance with *Figure 4.2.1 Compensation for welded standpipes or branches in cylindrical shells* with the value of A_1, the compensation required, calculated as follows:

$$A_1 = \frac{d_o}{2,4} t_f \text{ mm}^2$$

where

d_o = diameter of hole in flat plate, in mm

t_f = required thickness of the flat plate in the area under consideration, in mm, calculated in accordance with *Pt 15, Ch 4, 6.1 Minimum thickness 6.1.1*, as applicable, without corrosion allowance

Limit D = $0,5d_o$.

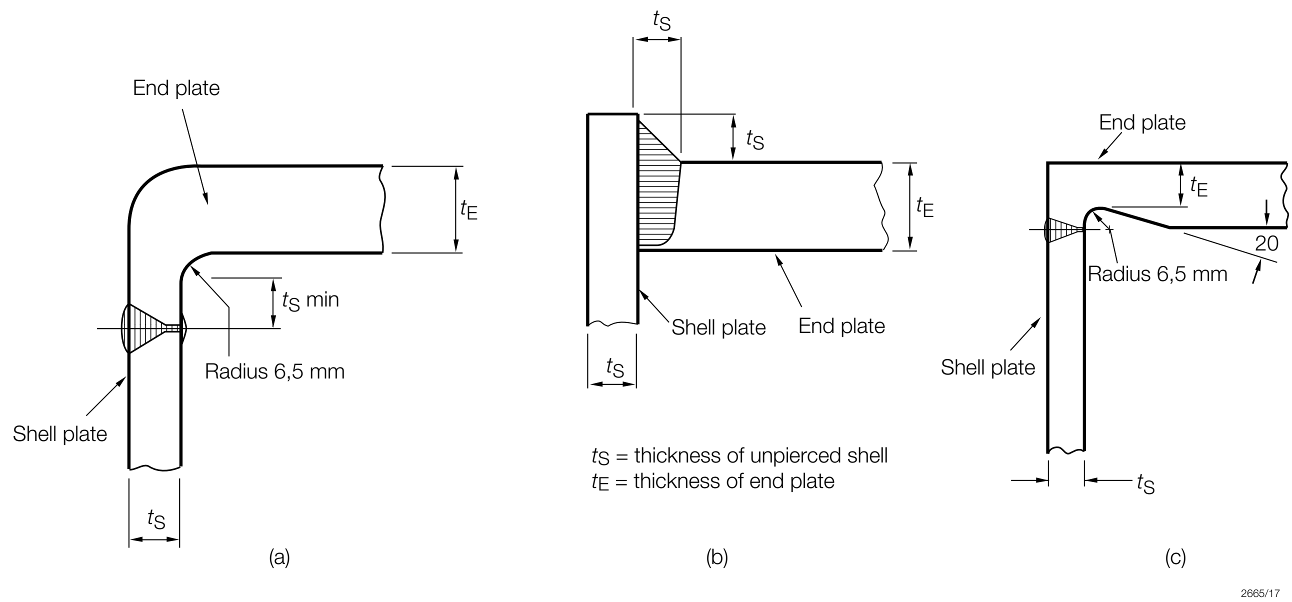


Figure 4.6.1 Typical methods of attachment of unstayed circular flat end plates

■ *Section 7* **Construction**

7.1 Access arrangements

7.1.1 Pressure vessels are to be so made that the internal surfaces may be examined. Wherever practicable, the openings for this purpose are to be sufficiently large for access and for cleaning the inner surfaces.

7.1.2 Manholes in cylindrical shells should preferably have their shorter axes arranged longitudinally.

7.1.3 Doors for manholes and sightholes are to be formed from the steel plate or of other approved construction, and all jointing surfaces are to be machined.

7.1.4 Doors of the internal type are to be provided with spigots which have a clearance of not more than 1,5 mm all round, i.e. the axes of opening are not to exceed those of the door by more than 3 mm. The width of the manhole gasket seat is not to be less than 16 mm.

7.1.5 Doors of the internal type for openings not larger than 230 x 180 mm need be fitted with only one stud, which may be forged integral with the door. Doors for openings larger than 230 mm x 180 mm are to be fitted with two studs or bolts. The strength of the attachment to the door is not to be less than the strength of the stud or bolt.

7.1.6 The crossbars or dogs for doors are to be of steel.

7.1.7 External circular flat cover plates are to be in accordance with a recognised standard.

7.2 Torispherical and semi-ellipsoidal ends

7.2.1 For typically acceptable types of attachment for dished ends to cylindrical shells, *see Figure 4.7.1 Typical attachment of dished ends to cylindrical shell*. Types (d) and (e) are to be made a tight fit in the cylindrical shell.

7.2.2 Where the difference in thickness is the same throughout the circumference, the thicker plate is to be reduced in thickness by machining to a taper for a distance not less than four times the offset, so that the two plates are of equal thickness at the position of the circumferential weld. A parallel portion may be provided between the end of the taper and the weld edge preparation; alternatively, if so desired, the width of the weld may be included as part of the smooth taper of the thicker plate.

7.2.3 The thickness of the plates at the position of the circumferential weld is to be not less than that of an unpierced cylindrical shell of seamless or welded construction, whichever is applicable, of the same diameter and material, *see Pt 15, Ch 4, 2.1 Minimum thickness*.

7.3 Welded-on flanges, butt welded joints and fabricated branch pieces

7.3.1 Flanges may be cut from plates or may be forged or cast. Hubbed flanges are not to be machined from plate. Flanges are to be attached to branches by welding. Alternative methods of flange attachment will be subject to special consideration.

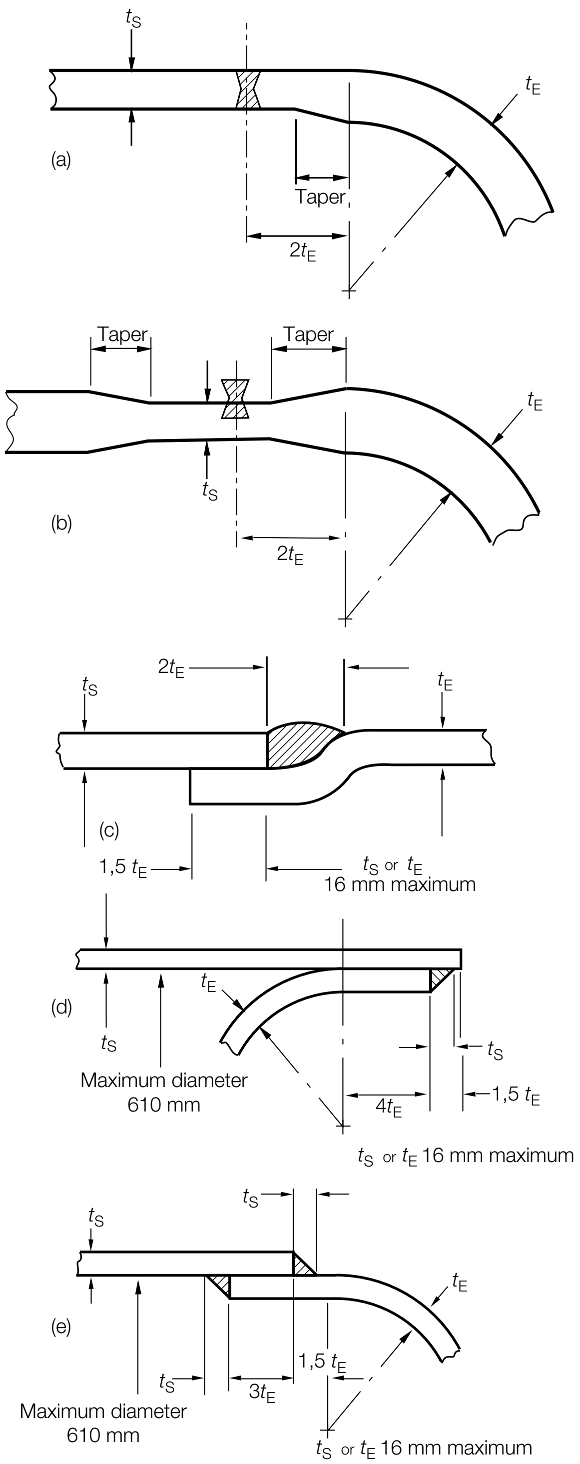
7.3.2 The types of welded-on flanges are to be suitable for the pressure, temperature and service for which the branches are intended.

7.3.3 Flange attachments and pressure-temperature ratings in accordance with materials and design of recognised standards will be accepted.

7.3.4 Typical examples of welded-on flange connections are shown in *Figure 4.7.2 Typical example of welded flange connections*, and limiting design conditions for the flange types are shown in *Table 4.7.1 Limiting design conditions for flanges*. In *Figure 4.7.2 Typical example of welded flange connections*, t is the minimum Rule thickness of the standpipe or branch.

7.3.5 Welded-on flanges are not to be a tight fit on the branch. The maximum clearance between the bore of the flange and the outside diameter of the branch is to be 3 mm at any point, and the sum of the clearances diametrically opposite is not to exceed 5 mm.

7.3.6 Where butt welds are employed in the attachment of flange type (a), or in the construction of standpipes or branch pieces, the adjacent pieces are to be matched at the bores. This may be effected by drifting, roller expanding or machining, provided the pipe wall is not reduced below the designed thickness. If the parts to be joined differ in wall thickness, the thicker wall is to be gradually tapered to that of the thinner at the butt joint.



Type of end attachment	Acceptable for
(a) and (b)	All classes
(c)	2/1, 2/2 and 3
(d) and (e)	Class 3 only

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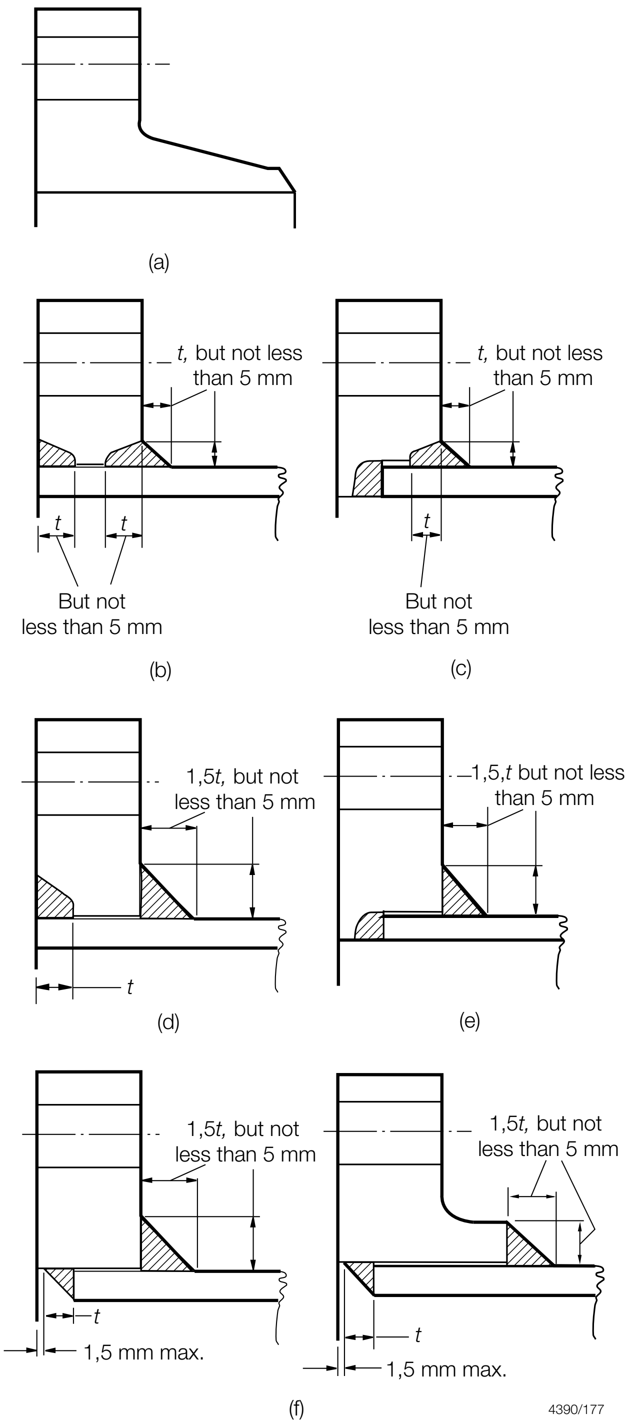
Figure 4.7.1 Typical attachment of dished ends to cylindrical shell



't' is the minimum Rule thickness of standpipe or branch

Figure 4.7.2 Typical example of welded flange connections

7.3.7 Welding may be carried out by means of the shielded metal arc, inert gas metal arc, oxy-acetylene or other approved process, but in general, oxy-acetylene welding is suitable only for flange type (a) and is not to be applied to branches exceeding 100 mm diameter or 9,5 mm thick.

7.3.8 Threaded sleeve joints complying with *Pt 15, Ch 1, 5.5 Threaded sleeve joints and threaded couplings 5.5.1* may be used on the steam and water piping of small oil fired package boilers of the once through coil type, used for auxiliary or domestic purposes, where the feed pump capacity limits the output.

7.3.9 Socket weld joints are not to be used where fatigue, severe erosion, crevice corrosion or stress corrosion are expected to occur, for example, blow down, drain, scum and chemical dosing connections.

7.4 Welded attachments to pressure vessels

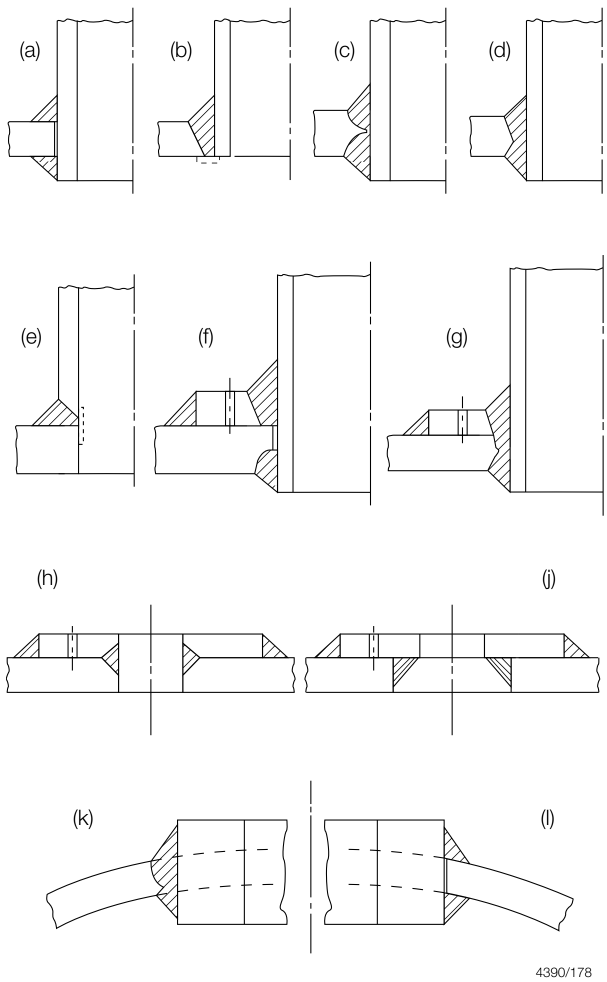
7.4.1 Unless the actual thickness of the shell or end is at least twice that required by calculation for a seamless shell or end, whichever is applicable, doubling plates with well rounded corners are to be fitted in way of attachments such as lifting lugs, supporting brackets and feet, to minimise load concentrations on pressure shells and ends. Compensating plates, pads, brackets and supporting feet are to be bedded closely to the surface before being welded, and are to be provided with a `tell-tale' hole not greater than 9,5 mm in diameter, open to the atmosphere to provide for the release of entrapped air during heat treatment of the vessel, or as a means of indicating any leakage during hydraulic testing and in service.

7.4.2 For acceptable methods of attaching standpipes, branches, compensating plates and pads, *see Figure 4.7.3* . Alternative methods of attachment may be accepted provided details are submitted for consideration.

7.4.3 Where fillet welds are used to attach standpipes, there are to be equal sized welds both inside and outside the vessel shell, *see Figure 4.7.3* (a) and (l). The leg length of each of the fillet welds is to be not less than the actual thickness of the thinner of the parts being joined.

Table 4.7.1 Limiting design conditions for flanges

Flange type	Maximum pressure	Maximum temperature	Maximum pipe o.d.	Minimum pipe bore
		ºC	mm	mm
(a)	Pressure temperature ratings to be in accordance with a recognised Standard	No restriction	No restriction	No restriction
(b)	Pressure temperature ratings to be in accordance with a recognised Standard	No restriction	168,3 for alloy steels*	No restriction
(c)	Pressure temperature ratings to be in accordance with a recognised Standard	No restriction	168,3 for alloy steels*	75
(d)	Pressure temperature ratings to be in accordance with a recognised Standard	425	No restriction	No restriction
(e)	Pressure temperature ratings to be in accordance with a recognised Standard	425	No restriction	75
(f)	Pressure temperature ratings to be in accordance with a recognised Standard	425	No restriction	No restriction
Note * No restriction for carbon steels				



Type (a) and (l) attachments are not to be used for openings which require to be compensated. Backing rings may be used with types (b) and (e).

■ *Section 8*
Requirements for fusion welded pressure vessels

8.1 General requirements

8.1.1 Welded construction of pressure vessels is to be in accordance with the requirements specified in *Ch 13, 1 General welding requirements* and *Ch 13, 4 Specific requirements for fusion welded pressure vessels* of the Rules for Materials.

8.1.2 Fusion welded pressure vessels constructed to Class 1 and Class 2/1 requirements will be accepted only if manufactured by firms equipped and competent to undertake high quality welding. In order that firms may be approved for this purpose, it will be necessary for the Surveyors to visit the works for the purpose of inspecting the welding plant equipment and procedures, and to arrange for the carrying out of preliminary tests as stated in *Ch 13, 4 Specific requirements for fusion welded pressure vessels* of the Rules for Materials.

Section 9
Mountings and fittings for pressure vessels

9.1 General

9.1.1 Each pressure vessel or system is to be fitted with a stop valve situated as close as possible to the shell.

9.1.2 Adequate arrangements are to be provided to prevent over-pressure of any part of a pressure vessel which can be isolated. Pressure gauges are to be fitted in positions where they can be easily read.

9.1.3 Adequate arrangements are to be provided for draining and venting the separate parts of each pressure vessel.

9.2 Receivers containing pressurised gases

9.2.1 Each air receiver is to be fitted with a drain arrangement at its lowest part, permitting oil and water to be blown out.

9.2.2 Each receiver which can be isolated from a relief valve is to be provided with a suitable fusible plug to discharge the contents in case of fire. The melting point of the fusible plug is to be approximately 150°C. *See also Pt 15, Ch 4, 9.2 Receivers containing pressurised gases 9.2.3* and *Pt 15, Ch 4, 9.2 Receivers containing pressurised gases 9.2.4*.

9.2.3 Where a fixed system utilising fire-extinguishing gas is fitted, to protect a machinery space containing an air receiver(s), fitted with a fusible plug, it is recommended that the discharge from the fusible plug be piped to the open deck.

9.2.4 Receivers used for the storage of air for the control of remotely operated valves are to be fitted with relief valves and not fusible plugs.

Section 10
Hydraulic tests

10.1 Fusion welded pressure vessels

10.1.1 Fusion welded pressure vessels are to be tested on completion to a pressure, p_T, determined by the following formula, without showing signs of weakness or defect:

$$p_T = 1{,}3 \frac{\sigma_{50}}{\sigma_t} \frac{t}{(t - 0{,}75)} p$$

but in no case is to exceed

$$\frac{t}{(t - 0{,}75)} p$$

where

p = design pressure, in MPa

p_T = test pressure, in MPa

t = nominal thickness of shell as indicated on the plan, in mm

σ_T = allowable stress at design temperature, in N/mm^2

σ_{50} = allowable stress at 50°C, in N/mm^2.

10.2 Mountings

10.2.1 Mountings are to be subjected to a hydraulic test of twice the approved design pressure.

Section 11
Fibre reinforced plastics pressure vessels

11.1 General

11.1.1 Pressure vessels may be constructed in fibre reinforced plastics provided the manufacturer is competent and suitably equipped for this purpose.

11.1.2 Pressure vessels are to be of standard design whose suitability has been established by fatigue and burst tests on a prototype.

11.2 Prototype testing

11.2.1 For the fatigue test the pressure shall be cycled from atmospheric to design pressure 100 000 times at the design temperature.

11.2.2 For the burst test the minimum bursting pressure shall be six times the design pressure.

11.3 Production hydraulic test

11.3.1 Vessels subject to internal pressure shall be hydraulically tested to not less than 1,5 times the design pressure.

Section 12
Requirements for craft which are not required to comply with the HSC Code

12.1 Fibre reinforced plastics pressure vessels

12.1.1 Fibre reinforced plastics pressure vessels, where the product of the design pressure in bar and volume in litres exceeds 600, are not to be situated in machinery spaces or high risk areas on yachts and service craft less than 24 m.

12.1.2 Small fibre reinforced plastics pressure vessels will receive special consideration in relation to their intended duty and service conditions.

Contents

■ *Section 1* General requirements

1.1 General

1.1.1 This Chapter applies to control engineering systems on special service craft.

1.1.2 Control engineering systems are to:

- provide control of required services and habitability requirements during defined operational conditions. This is to include, but is not limited to, power generation, propulsion and their associated services;
- provide control of the engineering systems necessary to ensure availability of essential and emergency safety systems during all normal and reasonably foreseeable abnormal conditions;
- provide control of the engineering systems necessary to ensure transitional power supplies remain available;
- be suitably protected against damage to itself under fault conditions and to prevent injury to personnel; and
- not fail in a way which may cause machinery and systems located in hazardous areas to create additional fire or explosion risk.

1.1.3 LR will be prepared to give consideration to special cases or to arrangements which are equivalent to the Rules where sufficient technical justification is provided.

1.2 Documentation required for design review

1.2.1 The documentation described in *Pt 16, Ch 1, 1.2 Documentation required for design review 1.2.2* is to be submitted for design review.

1.2.2 A description of operation with explanatory diagrams together with line diagrams of control circuits, list of monitored, control and alarm points is required for the following machinery or equipment:

- Fixed water-based local application fire-fighting systems, *see Pt 16, Ch 1, 2.9 Fixed water-based local application fire-fighting systems*.
- Air compressors
- Bilge systems.
- Controllable pitch propellers.
- Electric generating plant.
- Lithium battery system installations, *see also Pt 16, Ch 2, 1.2 Documentation required for design review 1.2.13*.
- Fuel oil transfer and storage systems.
- Propulsion machinery including essential auxiliaries.
- Steam raising plant (boilers and their ancillary equipment).
- Steering systems.
- Thermal fluid heaters.

- Thrust units.
- Valve position indicating systems.
- Water jets for propulsion purposes.
- Windlasses.

1.2.3 **Test schedules** (for both works testing and sea trials), which should include methods of testing (for example, simulation testing) and test facilities provided, *see Pt 16, Ch 1, 7.4 Record of trials 7.4.1*.

1.2.4 **System operational concept.** A description of the intended operation of the control, alarm, mointoring and safety systems for the main and auxiliary machinery, and other systems essential for the propulsion and safety of the ship. This description is to include a demonstration that the design provides an effective means of operation and control for all ship operating conditions.

1.2.5 **Alarm systems**. Details of the overall alarm system linking the main control station, subsidiary control stations, the bridge area and accommodation. Details of alarms and warnings presented by the user interface including: an approach to category assignment which is in accordance with the IMO *Code on Alerts and Indicators, 2009*; and for alarms required by these Rules, the intended operator response and the message is to be presented.

1.2.6 **Programmable electronic systems**.

In addition to the documentation required by *Pt 16, Ch 1, 1.2 Documentation required for design review 1.2.2*, the following is to be submitted:

(a) System requirements specification.
(b) System functional description.
(c) System integration plan, *see Pt 16, Ch 1, 2.14 Programmable electronic systems - Additional requirements for integrated systems 2.14.2*.
(d) Failure Mode and Effects Analysis (FMEA), *see Pt 16, Ch 1, 2.14 Programmable electronic systems - Additional requirements for integrated systems 2.14.5*.
(e) Details of the hardware configuration in the form of a system block diagram, including input/output schedules.
(f) Hardware certification details, *see Pt 16, Ch 1, 2.10 Programmable electronic systems – General requirements 2.10.5*and *Pt 16, Ch 1, 2.13 Programmable electronic systems – Additional requirements for essential services and safety critical systems 2.13.3*.
(g) Software production plans, including applicable procedures, *see Pt 16, Ch 1, 2.10 Programmable electronic systems – General requirements 2.10.20*.
(h) Factory acceptance, integration and sea trial test schedules for hardware and software.
(i) Details of data storage arrangements, *see Pt 16, Ch 1, 2.10 Programmable electronic systems – General requirements 2.10.10* and *Pt 16, Ch 1, 2.13 Programmable electronic systems – Additional requirements for essential services and safety critical systems 2.13.6*.

1.2.7 For wireless data communication equipment:

(a) Details of manufacturer’s installation and maintenance recommendations;
(b) network plan with arrangement and type of aerials and identification of location;
(c) specification of wireless communication system protocols and management functions, *see Pt 16, Ch 1, 2.12 Additional requirements for wireless data communication links 2.12.4*; and
(d) details of radio frequency and power levels, including details of those permitted by the National Administration.

1.2.8 **Control station**. Plans showing the location and details of control stations, e.g. control panels and consoles. Location and details of controls and displays on each panel. Detailed user interface specifications. A general arrangement plan of control rooms showing the position of consoles, handrails, operator area, lighting, door and window arrangements. Drawing of HVAC systems including vent arrangements.

1.2.9 **Fire detection systems**. Plans showing the system operation and the type and location of all machinery space fire detector heads, manual call points and the fire detector indicator panel(s). The plans are to indicate the position of the fire detectors in relation to significant items of machinery, ventilation and extraction openings.

1.3 Control, alarm and safety equipment

1.3.1 Equipment associated with control, alarm and safety systems as defined in *Pt 16, Ch 1, 1.2 Documentation required for design review* is to be surveyed at the manufacturers' works and the inspection and testing is to be to the Surveyor's satisfaction, *see also Pt 16, Ch 1, 1.2 Documentation required for design review 1.2.2*.

1.3.2 Equipment used in control, alarm and safety systems is to be suitable for its intended purpose, and accordingly, whenever practicable, be selected from the *List of Lloyd's Register Type Approved Products* published by Lloyd's Register (hereinafter referred to as 'LR').

1.3.3 Where equipment requires a controlled environment, an alternative means is to be provided to maintain the required environment in the event of a failure of the normal air conditioning system. Failure of the air conditioning system is to initiate an alarm.

1.3.4 Assessment of performance parameters, such as accuracy, repeatability, etc. are to be in accordance with an acceptable National or International Standard, e.g. IEC 60051:*Direct acting indicating analogue electrical measuring instruments and their accessories* (all parts).

1.4 Alterations and additions

1.4.1 When an alteration or addition to the approved system(s) is proposed, plans are to be submitted for approval. The alterations or additions are to be carried out under survey and the installation and testing are to be to the Surveyor's satisfaction.

1.4.2 Details of proposed software modifications are to be submitted for consideration. Modifications are to be undertaken in accordance with defined modification processes which are part of the supplier's or system integrator's quality management system. The following documentation is to be submitted:

(a) Project-specific software modification plan.
(b) An impact analysis which identifies the effect(s) of the proposed modification. The results of the analysis are to be used to inform the extent of verification and validation that is to be applied. This analysis is to consider both the local impact and, where applicable, the system level impact of the modification.
(c) Configuration management records that satisfy the requirements of ISO 10007, to demonstrate the traceability of the proposed modification.
(d) Factory acceptance, integration and sea trial test schedules as determined by the impact analysis in *Pt 16, Ch 1, 1.4 Alterations and additions 1.4.2.(b)*.
(e) Updated documentation as detailed in *Pt 16, Ch 1, 1.2 Documentation required for design review 1.2.5*

1.4.3 Verification and validation activities are to demonstrate that the modified functionality performs as expected and that the modification has not unintentionally modified functionality outside the scope of the modification.

1.4.4 Software versions are to be uniquely identified by number, date or other appropriate means. Modifications are not to be made without also changing the version identifier. A record of changes to the system since the original issue (and their identification) is to be maintained and made available to the LR Surveyor on request.

1.5 Definitions

1.5.1 An Emergency Stop (E-Stop) is a safeguard instigated by a single human action. It requires a stop of all movement within the controlled system as rapidly as possible to prevent a hazard occurring or to reduce an existing hazard to persons, machinery or the vessel.

1.5.2 An Emergency Trip (E-Trip) is a safeguard instigated by a single human action and means the disconnection of fuel, electrical, hydraulic or other power source from the controlled system to prevent a hazard occurring or to reduce an existing hazard to persons, machinery or the vessel. Movement within the system may be allowed to continue.

1.5.3 An Emergency Stop Function may be either an Emergency Stop or Emergency Trip, as appropriate to the system and risk being controlled.

1.5.4 Alarm System: a system which will alert relevant personnel to faults, abnormal situations and other conditions requiring attention in the machinery and the safety and control systems.

1.5.5 Control System: a system which responds to input signals from the process and/or operator and generates output signals causing the equipment under control to operate in the desired manner.

1.5.6 Failure: a loss of the ability of a structure, system or element to function within acceptance criteria.

1.5.7 Fail safe: a system design such that, when a failure occurs, the system reverts to the least hazardous state.

1.5.8 A reasonably foreseeable abnormal condition is an event, incident or failure that :

- has happened and could happen again;
- is planned for (e.g. emergency actions cover such a situation, maintenance is undertaken to prevent it, etc.).

They should be identified by:

- using analysis processes that were capable of revealing abnormal conditions;
- employing a mix of personnel including competent safety / risk professionals and those with relevant domain knowledge and understanding to apply the processes;
- referencing relevant events and historic data; and
- documenting the results of the analysis.

1.5.9 Safety System: a designated system that:

- implements the required safety functions necessary to achieve or maintain a safe state for the equipment under control; and
- is intended to achieve, on its own or with other safety systems, the necessary safety needed for the required safety functions.

1.5.10 Safe State: the state of equipment under control when safety is achieved. For some situations, a safe state only exists so long as the equipment under control is continuously controlled. Such continuous control may be for a short or indefinite period.

1.5.11 System: a set of elements which interact according to a design, where an element of a system can be another system, called a sub-system, which may be a controlling system or a controlled system, and may include hardware, software and human interaction.

1.5.12 Sub-system: identifiable part of a system, which may perform a specific function or set of functions.

1.5.13 Programmable electronic equipment: physical component where software is installed.

1.5.14 Software module:a module is a standalone piece of code that provides specific and closely coupled functionality.

1.5.15 Simulation tests: system testing where simulation tools replace parts or all of the equipment, or where parts of the communication network and lines are replaced with simulation tools.

■ *Section 2*
Essential features for control, alarm, monitoring and safety systems

2.1 General

2.1.1 Systems complying with ISO 17894, *Ships and marine technology - Computer applications - General principles for the development and use of programmable electronic systems in marine applications*, may be accepted as meeting the requirements of this Section in which case evidence of compliance is to be submitted for consideration.

2.2 Control stations for machinery

2.2.1 A system of alarm and warning displays and controls is to be provided which readily ensures identification of faults in the machinery and satisfactory supervision of related equipment by duty personnel. This may be provided at a main control station or, alternatively at subsidiary control stations. In the latter case, a master alarm display is to be provided at the main control station showing which of the subsidiary control stations is indicating a fault condition.

2.2.2 At the main control station (if provided) or close to the subsidiary stations (if fitted) means of two way voice communication with the bridge area, the accommodation for engineering personnel and, if necessary, the machinery spaces are to be provided.

2.2.3 Where operator interfaces are installed in the wheelhouse, illumination should not interfere with night vision. All illumination and lighting of instruments, keyboards and controls are to be adjustable to zero illumination, except for lighting for visual indication of alarms and the controls of dimmers, which are to remain readable.

2.2.4 Provision is to be made at the main control station, or subsidiary control stations as appropriate, for the operation of an engineers' alarm which is to be clearly audible in the engineers' accommodation.

2.2.5 Provision is to be made at the main control station and any other subsidiary control station from which the main propulsion and auxiliary machinery or associated equipment may be controlled to indicate which station is in control.

2.2.6 Control of machinery and associated equipment is to be possible only from one station at a time.

2.2.7 Changeover between control stations is to be arranged so that it may only be effected with the acceptance of the station taking control. The system is to be provided with interlocks or other suitable means to ensure effective transfer of control.

2.3 Alarm systems

2.3.1 Machinery, safety and control system faults are to be indicated at the relevant control stations to advise duty personnel of a fault condition. The presence of unrectified faults is to be clearly indicated at all times.

2.3.2 Alarms and warnings associated with machinery and equipment required to satisfy this sub-Section are to be categorised according to the urgency and type of response required by the crew, as described in the IMO *Code on Alerts and Indicators, 2009*. The assignment of the category to each alert is to be evaluated on the basis not only of the machinery or equipment being monitored, but also the complete installation. Categories not included in an alarm system may be omitted from the system design. Details of alternative alert management proposals supported with evidence of service experience, may be submitted for consideration by LR.

2.3.3 Where the facility to provide messages in association with alarms and warnings exists, messages accompanying alarms and warnings are to describe the condition and indicate the intended response required by the crew.

2.3.4 Where the facility to provide messages in association with alarms and warnings exists, messages of different categories are to be clearly distinguishable from each other.

2.3.5 Where alarms are displayed as group alarms provision is to be made to identify individual alarms at the main control station (if fitted) or alternatively at subsidiary control stations.

2.3.6 All alarms are to be both audible and visual. If arrangements are made to silence audible signals, they are not to extinguish visual indications.

2.3.7 Acknowledgement of visual alarms is to be clearly indicated.

2.3.8 Acknowledgement of alarms at positions outside a machinery space is not to silence the audible signal or extinguish the visual indication in that machinery space.

2.3.9 If an alarm has been acknowledged and a second fault occurs prior to the first being rectified, audible signals and visual indications are again to operate. Where alarms are displayed at a local panel adjacent to the machinery and with arrangements to provide a group or common fault alarm in the control room then the occurrence of a second fault prior to the first alarm being rectified need only be displayed at the local panel, however the group alarm is to be reinitiated. Unacknowledged alarms on monitors are to be distinguished by either flashing text or a flashing marker adjacent to the text. A change of colour will not in itself be sufficient to distinguish between acknowledged and unacknowledged alarms.

2.3.10 For the detection of transient faults which are subsequently self-correcting, alarms are required to lock in until accepted.

2.3.11 The alarm system is to be arranged with automatic changeover to a standby power supply in the event of a failure of the normal power supply. Where an alarm system could be adversely affected by an interruption in power supply, changeover to the standby power supply is to be achieved without a break.

2.3.12 Failure of any power supply to the alarm system is to operate an audible and visual alarm.

2.3.13 The alarm system should be designed with self-monitoring properties. Insofar as practicable, any fault in the alarm system should cause it to fail to the alarm condition.

2.3.14 The alarm system is to be capable of being tested during normal machinery operation, *see Pt 16, Ch 1, 7.1 General 7.1.2*.

2.3.15 The alarm system is to be designed as far as practicable to function independently of control and safety systems such that a failure or malfunction in these systems will not prevent the alarm system from operating.

2.3.16 Disconnection or manual overriding of any part of the alarm system is to be clearly indicated.

2.3.17 When alarm systems are provided with means to adjust their set point, the arrangements are to be such that the final settings can be readily identified.

2.3.18 Where monitors are provided at the station in control and, if fitted, in the duty engineer's accommodation, they are to provide immediate display of new alarm information regardless of the information display page currently selected. This may be achieved by provision of a dedicated alarm monitor, a dedicated area of screen for alarms or other suitable means.

2.3.19 Where practicable, alarms displayed on monitors are to be displayed in the order in which they occur. Alarms requiring manual shutdown or slowdown action are to be given visual prominence.

2.4 Safety systems, general requirements

2.4.1 Safety systems are to operate automatically in case of serious faults endangering the machinery, so that:

(a) normal operating conditions are restored, e.g. by the starting of standby machinery, or
(b) the operation of the machinery is temporarily adjusted to the prevailing conditions, e.g. by reducing the output of the machinery, or
(c) the machinery is protected from critical conditions by shutting off the fuel or power supplies thereby stopping the machinery.

2.4.2 The safety system required by *Pt 16, Ch 1, 2.4 Safety systems, general requirements 2.4.1.(c)* is to be designed as far as practicable to operate independently of the control and alarm systems, such that a failure or malfunction in the control and alarm systems will not prevent the safety system from operating.

2.4.3 For safety systems required by *Pt 16, Ch 1, 2.4 Safety systems, general requirements 2.4.1* and *Pt 16, Ch 1, 2.4 Safety systems, general requirements 2.4.1.(b)* complete independence from other control systems is not necessary.

2.4.4 Safety systems for different items of the machinery plant are to be arranged so that failure of the safety system of one part of the plant will not interfere with the operation of the safety system in another part of the plant.

2.4.5 The safety system is to be designed to `fail safe'. The characteristics of the `fail safe' operation are to be evaluated on the basis not only of the safety system and its associated machinery, but also the complete installation. Failure of a safety system is to initiate an audible and visual alarm.

2.4.6 When a safety system is activated, an audible and visual alarm is to be provided to indicate the cause of the safety action.

2.4.7 The safety system is to be manually reset before the relevant machinery can be restarted.

2.4.8 Where arrangements are provided for overriding a safety system, they are to be such that inadvertent operation is prevented. Visual indication is to be given at the relevant control station(s) when a safety override is operated. High speed craft are to be provided with arrangements for overriding automatic shutdown systems except in cases where there is a risk of complete breakdown or explosion.

2.4.9 The safety system is to be arranged with automatic changeover to a standby power supply in the event of a failure of the normal power supply.

2.4.10 Failure of any power supply to a safety system is to operate an audible and visual alarm.

2.4.11 When safety systems are provided with means to adjust their set point, the arrangements are to be such that the final settings can be readily identified.

2.5 Control systems

2.5.1 Control systems for machinery operations are to be stable throughout their operating range.

2.5.2 The control system is to be designed such that normal operation of the controls cannot induce detrimental mechanical or thermal overloads in the machinery.

2.5.3 When control systems are provided with means to adjust their sensitivity or set point, the arrangements are to be such that the final settings can be readily identified.

2.5.4 Control systems are to be designed to `fail safe'. The characteristics of the `fail safe' operation are to be evaluated on the basis not only of the control system and its associated machinery, but also the complete installation.

2.5.5 Failure of any power supply to a control system is to operate an audible and visual alarm.

2.5.6 Where machinery is fitted with automatic or remote controls so that under normal operating conditions it does not require any manual intervention by the operators, it is to be provided with the alarms and safety arrangements required by the appropriate Chapter(s). Alternative arrangements which provide equivalent safeguards will be considered.

2.5.7 Remote or automatic controls are to be provided with sufficient instrumentation at the relevant control stations to ensure effective control by duty personnel and to indicate that the system is functioning correctly.

2.5.8 Where machinery is arranged to start automatically or from a remote control station, interlocks are to be provided to prevent start-up under conditions which could hazard the machinery.

2.5.9 Where machinery, controlled in accordance with *Pt 16, Ch 1, 2.5 Control systems 2.5.6*, is required to be provided with a standby pump, the standby pump is to start automatically if the discharge pressure from the working pumps falls below a predetermined value.

2.5.10 Failure of a control system is not to result in the loss of ability to provide essential services by alternative means. This may be achieved by manual control or redundancy within the control system or redundancy in machinery and equipment, *see also Pt 16, Ch 1, 2.13 Programmable electronic systems – Additional requirements for essential services and safety critical systems 2.13.2*. Instrumentation is to be provided at local manual control stations to ensure effective operation of the machinery by duty personnel.

2.6 Bridge control for propulsion machinery

2.6.1 Means are to be provided to ensure satisfactory control of propulsion from the bridge in both the ahead and astern directions.

2.6.2 Two independent means are to be provided on the bridge to enable the watchkeeper to stop the propulsion machinery in an emergency.

2.6.3 Audible and visual alarms are to operate on the bridge and in the machinery alarm system if any power supply to the bridge control system fails. Where practicable the preset speed and direction of thrust are to be maintained until corrective action is taken.

2.6.4 Cargo (B) high speed craft are to be provided with a standby system for controlling propulsion machinery. A standby system controllable from an engine control space such as an engine control room outside the bridge is acceptable.

2.6.5 Passenger (B) high speed craft are to be provided with a standby system for controlling propulsion machinery from the bridge.

2.6.6 Passenger (B) high speed craft are to be provided with additional control of propulsion and manoeuvring at the same location as the emergency functions referred to in Ch 2,16.5.6. Such stations are to have direct communication with the bridge area.

2.6.7 For high speed craft, failure of the operating propulsion control system or of transfer of control is to bring out the craft to low speed without hazarding passengers or craft.

2.7 Valve control systems

2.7.1 Where cargo, bilge, ballast, fuel oil transfer and sea valves for engine services are operated by remote or automatic control, the requirements of *Pt 16, Ch 1, 2.7 Valve control systems 2.7.2* are to be satisfied.

2.7.2 Failure of actuator power is not to permit a valve to move to an unsafe condition.

2.7.3 Positive indication is to be provided at the remote control station for the service to show the actual valve position or alternatively that the valve is fully open or closed.

2.7.4 Equipment located in places which may be flooded is to be capable of operating when submerged.

2.7.5 A secondary means of operating the valves, which may be by local manual control, is to be provided.

2.7.6 For requirements applicable to closing appliances on scuppers and sanitary discharges, *see Pt 3, Ch 4, 9.4 Scupper arrangements*. For power supplies on passenger craft, *see Pt 16, Ch 2, 3.2 Emergency source of electrical power in passenger craft and for yachts that are 500 gt or more*.

2.8 Fire detection and fire alarm systems

2.8.1 Fire detection and fire alarm systems are to comply with *Chapter 9 – Fixed fire detection and fire alarm systems* of the *Fire Safety Systems Code* (FSS Code), *Pt 17 Fire Protection, Detection and Extinction* and the requirements in this Section as applicable.

2.8.2 Fire detection control units, indicating panels, detector heads, manual call points and short-circuit isolation units are to be type approved in accordance with Test Specification Number 1 given in LR's *Type Approval* System for an environmental category appropriate for the locations in which they are intended to operate.

2.8.3 The alarm system is to be designed with selfmonitoring properties. Power or system failures are to initiate an audible alarm distinguishable from the fire-alarm. This alarm may be incorporated in the machinery alarm system as required by *Pt 16, Ch 1, 2.3 Alarm systems*.

2.8.4 When fire detectors are provided with means to adjust their sensitivity, the arrangements are to be such that the set point can be fixed and readily identified.

2.8.5 The fire detector heads are to be of a type which can be tested and reset without the renewal of any component. Facilities are to be provided on the fire-control panel for functional testing and reset of the system.

2.8.6 When it is intended that a particular loop is to be temporarily switched off, this state is to be clearly indicated at the fire detection indicating panels.

2.8.7 When it is intended that a particular detector(s) is (are) to be temporarily switched off locally, this state is to be clearly indicated at the local position. Reactivation of the detector(s) is to be performed automatically after a preset time.

2.8.8 It is to be demonstrated to the Surveyor's satisfaction that detector heads are so located that air currents will not render the system ineffective whether the craft is at sea or in port.

2.8.9 An audible fire-alarm is to be provided having a characteristic which distinguishes it from the alarm system required by *Pt 16, Ch 1, 2.3 Alarm systems* or any other alarm system.

2.8.10 Where an automatic fire detection system is to be fitted in a machinery space, the requirements of *Pt 16, Ch 1, 2.8 Fire detection and fire alarm systems 2.8.11* to *Pt 16, Ch 1, 2.8 Fire detection and fire alarm systems 2.8.15* are also to be satisfied. *See also* SOLAS 1974, as amended Chapter II-2, Part C, *Regulation 7 - Detection and alarm*, or *Pt 17 Fire Protection, Detection and Extinction* as applicable.

2.8.11 Detector heads are to be located in the machinery spaces so that all potential fire outbreak points are guarded. A combination of detectors is to be provided to ensure that the system will react to all possible fire characteristics.

2.8.12 Fire detection indicating panels are to denote the section in which a detector or manually operated call point has operated. At least one indicating panel is to be so located that it is easily accessible to responsible members of the crew at all times. An indicating panel is to be located on the navigating bridge, together with TV monitoring in the case of high speed craft.

2.8.13 A fire detection control unit is to be located in the navigating bridge area, the fire-control station, or in some other position such that a fire in the machinery spaces will not render it inoperable.

2.8.14 The audible fire-alarm is to be immediately audible on all parts of the navigating bridge, at the fire-control station and the machinery control stations, and throughout the crew accommodation areas and the machinery spaces.

2.8.15 Facilities are to be provided in the fire detection system to initiate manually the fire-alarm from the following locations:

(a) Positions adjacent to all exits from machinery spaces.
(b) Navigating bridge.
(c) Control station in engine room.
(d) Fire control station.

2.8.16 Fire detection systems within the accommodation spaces and cabin balconies are also to comply with *Pt 16, Ch 1, 2.8 Fire detection and fire alarm systems 2.8.17*.

2.8.17 In yachts, the fixed fire detection and fire-alarm systems are to be capable of remotely and individually identifying each detector and manually operated call point. On other craft, indicating units are to denote, as a minimum, the section in which a detector or manually operated call point has operated. At least one indicating unit is to be so located that it is easily accessible to responsible members of the crew. One indicating unit is to be located on the navigating bridge if the control panel is located in the central control station.

2.8.18 Clear information is to be displayed on or adjacent to each indicating unit regarding the spaces covered and the location of the section and, for yachts, each detector and manually operated call point.

2.8.19 The fire detection system is not to be used for any other purpose, except that closing of fire doors and similar functions may be permitted at the control panel. For craft required to comply with the HSC Code, the control panel may be used to activate a paging system, fan stops, closure of fire doors, closure of fire and smoke dampers, and/or a sprinkler system.

2.8.20 In passenger craft other than yachts, where the fire detection system does not include means of remotely identifying each detector individually, a section of detectors is neither to serve spaces on both sides of the craft nor on more than one deck, except when permitted by *Pt 16, Ch 2, 17.1 Fire detection and fire alarm systems 17.1.8*.

2.8.21 A section of fire detectors and manually operated call points which covers a control station, a service space or an accommodation space is not to include a machinery space of Category A.

2.8.22 The fire control panel is to be located on the navigating bridge or in a central fire-control station and may form part of that panel specified in *Pt 16, Ch 1, 2.8 Fire detection and fire alarm systems 2.8.12*. In passenger craft carrying more than 36 passengers, the fire-control panel is to be located in the continuously manned central control station.

2.8.23 Detectors and manually operated call points are to be grouped into sections. The activation of any detector or manually operated call point is to initiate a visual and audible fire signal at the control panel and indicating units. If the signals have not received attention within two minutes an audible alarm is to be automatically sounded throughout the crew accommodation and service spaces, control stations and machinery spaces of Category A. For craft required to comply with the HSC Code, there is to be no time delay for the audible alarms in crew accommodation areas, following initiation of an audible and visual alarm at the control panel and indicating units, when all the control stations are unattended. This alarm sounder system need not be an integral part of the detection system.

2.8.24 For electrical engineering requirements, *see Pt 16, Ch 2, 17.1 Fire detection and fire alarm systems*.

2.9 Fixed water-based local application fire-fighting systems

2.9.1 Where fixed water-based local application firefighting systems are required to be installed by National Administration requirements, arrangements are to be in accordance with this sub-Section.

2.9.2 Systems are to be available for immediate use and arranged for manual activation from inside and outside the protected space. *See also Pt 16, Ch 2, 17.3 Fixed water-based local application fire-fighting systems 17.3.4*.

2.9.3 Activation of a system is not to result in loss of electrical power or reduction of the manoeuvrability of the craft and is not to require confirmation of space evacuation or sealing, *see also Pt 16, Ch 2, 17.3 Fixed water-based local application fire-fighting systems 17.3.12*.

2.9.4 System zones and protected areas are to be arranged to allow essential services to be provided by machinery and/or equipment located outside areas affected by direct spray or extended water in the event of a system activation, where the machinery and/or equipment is duplicated or otherwise replicated to provide redundancy.

2.9.5 A control panel is to be provided for managing actions such as opening of valves, starting of pumps and initiation of alarms and warnings and processing information from detectors. This panel is to be independent of the fire detection control unit required by *Pt 16, Ch 1, 2.8 Fire detection and fire alarm systems*.

2.9.6 Alarms are to be initiated upon activation of a system and are to indicate the specific zone released at the control panel. Alarms are to be provided in each protected space, at an attended machinery control station and in the wheelhouse. The audible alarm is to be distinguishable from other safety system alarms.

2.9.7 A failure in a manual system activation switch circuit is not to prevent system activation using other installed manual system activation switches or, where installed, automatic activation. The means of activation are to be provided with self-monitoring facilities which will activate an alarm at an attended control station in the event of failure detection.

2.9.8 Where, additionally, the system is required to be capable of automatic release, the arrangements are to be in accordance with *Pt 16, Ch 1, 2.9 Fixed water-based local application fire-fighting systems 2.9.9* to *Pt 16, Ch 1, 2.9 Fixed water-based local application fire-fighting systems 2.9.12*.

2.9.9 A minimum of two fire detectors are to be provided for each protected area. One is to be a flame detector and the other is to be a smoke or heat detector, as considered appropriate to the nature of the risk and ambient conditions. The system is to be activated upon detection by two of the detectors. A fault in one detector is to initiate an alarm at an attended control station and is not to inhibit activation of the system under the control of the other detector or manually.

2.9.10 The fire detectors are to be arranged (located, oriented, guarded, etc.) to ensure that a fire in one protected area will not result in the inadvertent automatic activation of a system for another protected area. Guards or barriers provided to comply with this requirement are not to reduce the ability to detect a fire in the protected area.

2.9.11 A fire detection alarm system panel in accordance with *Pt 16, Ch 1, 2.8 Fire detection and fire alarm systems* may be used for receiving fire detection signals. Separate loops are not required provided that the address of the initiating device can be

identified at the control panel. The received signals are then to be sent to the control panel required by *Pt 16, Ch 1, 2.9 Fixed water-based local application fire-fighting systems 2.9.5* for processing and action.

2.9.12 The system's fire detection systems and control units are to meet the performance criteria stipulated by the National Administration and are to be Type Approved in accordance with *Test Specification Number 1* given in LR's Type Approval System for an environmental category appropriate for the locations in which they are intended to operate.

2.10 Programmable electronic systems – General requirements

2.10.1 The requirements of this sub-Section are to be complied with where control, alarm, moinitoring or safety systems incorporate programmable electronic equipment. Systems for essential services and safety critical applications, systems incorporating shared data communication links and systems which are integrated are to comply with the additional requirements of *Pt 16, Ch 1, 2.11 Data communication links*, *Pt 16, Ch 1, 2.13 Programmable electronic systems – Additional requirements for essential services and safety critical systems* and *Pt 16, Ch 1, 2.14 Programmable electronic systems - Additional requirements for integrated systems*, as applicable. For systems complying with ISO 17894, *Ships and marine technology - Computer applications - General principles for the development and use of programmable electronic systems in marine applications*, *see Pt 16, Ch 1, 2.13 Programmable electronic systems – Additional requirements for essential services and safety critical systems*.

2.10.2 Where programmable electronic systems share resources, any components that can affect the ability to effectively provide required control, alarm or safety functions are to fulfil the requirements of *Pt 16, Ch 1, 2.10 Programmable electronic systems – General requirements* to *Pt 16, Ch 1, 2.14 Programmable electronic systems - Additional requirements for integrated systems* related to providing those required functions.

2.10.3 Programmable electronic equipment is to revert to a defined safe state on initial start up or re-start in the event of failure.

2.10.4 In the event of failure of any programmable electronic equipment, the system and any other system to which it is connected, is to fail to a defined safe state or maintain safe operation, as applicable.

2.10.5 Programmable electronic equipment is to be certified by a recognised authority as suitable for the environmental conditions in which it is intended to operate, *see also Pt 16, Ch 1, 2.13 Programmable electronic systems – Additional requirements for essential services and safety critical systems 2.13.3*

2.10.6 Emergency stop functions are to be hard-wired and independent of any programmable electronic equipment. Alternatively, the system providing emergency stop functions is to comply with the requirements of *Pt 16, Ch 1, 2.13 Programmable electronic systems – Additional requirements for essential services and safety critical systems 2.13.2* and/or *Pt 16, Ch 1, 2.13 Programmable electronic systems – Additional requirements for essential services and safety critical systems 2.13.8*.

2.10.7 Programmable electronic equipment is to be provided with self-monitoring capabilities such that hardware and functional failures will initiate an audible and visual alarm in accordance with the requirements of *Pt 16, Ch 1, 2.3 Alarm systems* and, where applicable, *Pt 16, Ch 1, 4.2 Alarm system for machinery* . Hardware failures indications are to enable faults to be identifiable at least down to the level of the lowest replaceable unit and the self-monitoring capabilities are to ensure that diagnostic information is readily available.

2.10.8 Means are to be provided to recover or replace data required for safe and effective system operation lost as a result of component failure. The submission required by *Pt 16, Ch 1, 1.2 Documentation required for design review 1.2.6* is to address reinstatement of system operation following data loss.

2.10.9 System configuration, programs and data are to be protected against loss or corruption in the event of failure of any power supply. For essential services and safety critical systems, *see Pt 16, Ch 1, 2.13 Programmable electronic systems – Additional requirements for essential services and safety critical systems 2.13.6*.

2.10.10 Where it is necessary to store data required for system operation in volatile memory, a back-up power supply is to be provided that prevents data loss in the event of loss of the normal power supply. The submission required by *Pt 16, Ch 1, 1.2 Documentation required for design review 1.2.6* is to include details of any routine maintenance necessary and the measures necessary to restore system operation in the event of data loss as a result of power supply failure.

2.10.11 Back-up power supplies required by *Pt 16, Ch 1, 2.10 Programmable electronic systems – General requirements 2.10.10* are to be rated to supply the connected load for a defined period of time that allows sufficient time to restore the supply in the event of loss of the normal power supply as a result of failure of a main source of electrical power. This period is not to be less than 30 minutes.

2.10.12 Where regular battery replacement is required to maintain the availability of volatile memory back-up power supply required by *Pt 16, Ch 1, 2.10 Programmable electronic systems – General requirements 2.10.10*, these are to be included in the schedule of batteries required by *Pt 16, Ch 2, 1.2 Documentation required for design review 1.2.10* and *Pt 16, Ch 2, 12.7*

Recording of batteries for emergency and essential services, irrespective of battery type and size. Applicable entries in this schedule are to note that these batteries are not for safety critical systems or essential or emergency services.

2.10.13 Access to system configuration, programs and data is to be restricted by physical and/or logical means providing effective security against unauthorised alteration both for local and remote access.

2.10.14 Where date and time information is required by the equipment, this is to be provided by means of a battery backed clock with restricted access for alteration. Date and time information is to be fully represented and utilised.

2.10.15 Displays and controls are to be protected against liquid ingress due to spillage.

2.10.16 Display units are to comply with the requirements of an acceptable National or International Standard, e.g. IEC 60950-1: *Information technology equipment – Safety – Part 1: General requirements*, in respect of emission of ionising radiation.

2.10.17 Where systems detect fault conditions, any affected mimic diagrams are to ensure that the status of unreliable and incorrect data is clearly identified.

2.10.18 Multi-function displays and controls are to be duplicated and interchangeable where used for the control or monitoring of more than one system, machinery item or item of equipment. At least one unit at the main control station is to be supplied from an independent uninterruptible power system (UPS).

2.10.19 The number of multi-function display and control units provided at the main control station and their power supply arrangements are to be sufficient to ensure continuing safe operation in the event of failure of any unit or any power supply.

2.10.20 Software lifecycle activities, e.g. design, development, supply and maintenance, are to be carried out in accordance with an acceptable quality management system which has lifecycle models suitable to the nature of the software project, considering its size, complexity, safety, risk and integrity. Project specific software quality plans are to be submitted. These are to demonstrate that the provisions of ISO/IEC 90003: *Software engineering – Guidelines for the application of ISO 9001:2015 to computer software*, or equivalent, are incorporated. The plans are to define responsibilities for the lifecycle activities, including verification, validation, software module testing, integration with other components or systems and security policies to be applied.

2.11 Data communication links

2.11.1 Where control, alarm or safety systems use shared data communication links to transfer data, the requirements of *Pt 16, Ch 1, 2.11 Data communication links 2.11.2* are to be complied with. The requirements apply to local area networks, fieldbuses and other types of data communication link which make use of a shared medium to transfer control, alarm or safety related data between distributed programmable electronic equipment or systems.

2.11.2 Data communication is to be automatically restored within 45 seconds in the event of a single component failure. Upon restoration, priority is to be given to updating safety critical data and control, alarm and safety related data for essential services. Components comprise all items required to facilitate data communication, including cables, switches, repeaters, software components and power supplies.

2.11.3 Loss of a data communication link is not to result in the loss of ability to operate any essential service by alternative means, *see also Pt 16, Ch 1, 2.13 Programmable electronic systems – Additional requirements for essential services and safety critical systems 2.13.2*.

2.11.4 The properties of the data communication link, (e.g. bandwidth, access control method, etc.), are to ensure that all connected systems will operate in a safe, stable and repeatable manner under all operating conditions. The latency of control, alarm and safety related data is not to exceed two seconds.

2.11.5 Protocols are to ensure the integrity of control, alarm and safety related data, and provide timely recovery of corrupted or invalid data.

2.11.6 Means are to be provided to monitor performance and identify hardware and functional failures. An audible and visual alarm is to operate in accordance with the requirements of *Pt 16, Ch 1, 2.3 Alarm systems* and, where applicable, *Pt 16, Ch 1, 4.2 Alarm system for machinery* in the event of a failure of an active or standby component.

2.11.7 System self-monitoring capabilities are to be arranged to initiate transition to a defined safe state for the complete installation in the event of data communication failure, *see also Pt 16, Ch 1, 2.5 Control systems 2.5.4*.

2.11.8 Means are to be provided to prevent unintended connection or disconnection of any equipment where this may affect the performance of any other systems in operation.

2.11.9 Data cables are to comply with the applicable requirements of *Pt 16, Ch 2, 11 Electric cables, optical fibre cables and busbar trunking systems (busways)*. Other media will be subject to special consideration.

2.11.10 The installation is to provide adequate protection against mechanical damage and electromagnetic interference.

2.11.11 Components are to be located with appropriate segregation such that the risk of mechanical damage or electromagnetic interference resulting in the loss of both active and standby components is minimised. Duplicated data communication links are to be routed to give as much physical separation as is practical.

2.12 Additional requirements for wireless data communication links

2.12.1 The requirements of this sub-Section are in addition to *Pt 16, Ch 1, 2.11 Data communication links* and apply to systems incorporating wireless data communication links.

2.12.2 Wireless data communication links are not to be used for safety critical systems or essential services that are required for the propulsion or safety of the craft, except as permitted by *Pt 16, Ch 1, 2.12 Additional requirements for wireless data communication links 2.12.3*.

2.12.3 For services not required to operate continuously, wireless data communication links may be considered where an alternative means of operation that can be brought into action within an acceptable period of time is provided.

2.12.4 Wireless data communication is to employ recognised international wireless communication system protocols that incorporate the following:

(a) Message integrity: fault prevention, detection, diagnosis and correction, ensuring that the received message is not corrupted or altered when compared to the transmitted message.
(b) Configuration and device authentication: is to permit connection only of devices that are included in the system design.
(c) Message encryption: protection of the confidentiality and/or criticality of the data content.
(d) Security management: protection of network assets and prevention of unauthorised access to network assets.

2.12.5 The wireless system is to comply with the radio frequency and power level requirements of the International Telecommunications Union and any requirements of the National Administration with which the craft is registered.

2.12.6 Compliance with different port state and local regulations pertaining to the use of radio-frequency transmission that would prohibit the operation of a wireless data communication link, due to frequency and power level restrictions, is not addressed by these requirements and is the responsibility of the Owner and Operator.

2.13 Programmable electronic systems – Additional requirements for essential services and safety critical systems

2.13.1 The requirements of *Pt 16, Ch 1, 2.13 Programmable electronic systems – Additional requirements for essential services and safety critical systems 2.13.2* to *Pt 16, Ch 1, 2.13 Programmable electronic systems – Additional requirements for essential services and safety critical systems 2.13.10* are to be complied with where control, alarm, monitoring or safety systems for essential services, as defined by *Pt 16, Ch 2, 1.6 Definitions*, or safety critical systems, incorporate programmable electronic equipment:

(a) Safety critical systems are those which provide functions intended to protect persons from physical hazards (e.g. fire, explosion, etc.), or to prevent mechanical damage which may result in the loss of an essential service (e.g. main engine low lubricating oil pressure shutdown).
(b) Applications that are not essential services may also be considered to be safety critical (e.g. domestic boiler low water level shutdown).

2.13.2 Alternative means of safe and effective operation are to be provided for essential services and, wherever practicable, these are to be by provision of a fully independent hard wired back-up system. Where these alternative means are not independent of any programmable electronic equipment, the software is to satisfy the requirements of LR's *Software Conformity Assessment System - Assessment Module GEN1 (1994)*.

2.13.3 Items of programmable electronic equipment used to implement control, alarm or safety functions are to be Type Approved in accordance with LR's *Type Approval System Test Specification Number 1* (2002). Type approval to an alternative and relevant National or International Standard may be submitted for consideration.

2.13.4 The system is to be configured such that control, alarm and safety function groups are independent. A failure of the system is not to result in the loss of more than one of these function groups. Proposals for alternative arrangements providing an equivalent level of safety will be subject to special consideration.

2.13.5 For essential services, the system is to be arranged to operate automatically from an alternative power supply in the event of a failure of the normal supply.

2.13.6 Volatile memory is not to be used to store data required for:

- an essential service or safety critical functions; or
- ensuring safety or preventing damage, including during start-up or re-start.

Alternative proposals which demonstrates that an equivalent level of system integrity will be achieved may be submitted for consideration.

2.13.7 Failure of any power supply is to initiate an audible and visual alarm in accordance with the requirements of *Pt 16, Ch 1, 2.3 Alarm systems* and, where applicable, *Pt 16, Ch 1, 4.2 Alarm system for machinery* .

2.13.8 Where it is intended that the programmable electronic system implements an emergency stop function or safety critical functions, the software is to satisfy the requirements of LR's *Software Conformity Assessment System- Assessment Module GEN1 (1994)*. Alternative proposals providing an equivalent level of system integrity will be subject to special consideration, e.g. fully independent hard wired back-up system, redundancy with design diversity, etc.

2.13.9 Control, alarm and safety related information is to be displayed in a clear, unambiguous and timely manner, and, where applicable, is to be given visual prominence over other information on the display.

2.13.10 Means of access to safety critical functions are to be dedicated to the intended function and readily distinguishable.

2.14 Programmable electronic systems - Additional requirements for integrated systems

2.14.1 The requirements of *Pt 16, Ch 1, 2.14 Programmable electronic systems - Additional requirements for integrated systems 2.14.2* to *Pt 16, Ch 1, 2.14 Programmable electronic systems - Additional requirements for integrated systems 2.14.7* apply to integrated systems providing control, alarm or safety functions in accordance with the Rules, including systems capable of independent operation interconnected to provide co-ordinated functions or common user interfaces. Examples include integrated machinery control, alarm and monitoring systems, power management systems and safety management systems providing a grouping of fire, passenger, crew or craft safety functions, *see Pt 16, Ch 2, 17 Fire safety systems*.

2.14.2 System integration is to be managed by a single designated party, and is to be carried out in accordance with a defined procedure identifying the roles, responsibilities and requirements of all parties involved. This procedure is to be submitted for consideration where the integration involves control functions for essential services or safety functions including fire, passenger, crew, and craft safety.

2.14.3 The system requirements specification, *see Pt 16, Ch 1, 1.2 Documentation required for design review 1.2.6*, is to identify the allocation of functions between modules of the integrated system, and any common data communication protocols or interface standards required to support these functions.

2.14.4 Reversionary modes of operation are to be provided to ensure safe and graceful degradation in the event of one or more failures. In general, the integrated system is to be arranged such that the failure of one part will not affect the functionality of other parts, except those that require data from the failed part.

2.14.5 Where the integration involves control functions for essential services or safety functions, including fire, passenger, crew and craft safety, a Failure Mode and Effects Analysis (FMEA) is to be carried out in accordance with IEC 60812: *Analysis techniques for system reliability – Procedure for failure mode and effects analysis (FMEA)*, or an equivalent and acceptable National or International Standard and the report and worksheets submitted for consideration. The FMEA is to demonstrate that the integrated system will 'fail-safe', *see Pt 16, Ch 1, 2.4 Safety systems, general requirements 2.4.5* and *Pt 16, Ch 1, 2.5 Control systems 2.5.4*, and that essential services in operation will not be lost or degraded beyond acceptable performance criteria where specified by these Rules.

2.14.6 The quantity and quality of information presented to the operator are to be managed to assist situational awareness in all operating conditions. Excessive or ambiguous information that may adversely affect the operator's ability to reason or act correctly is to be avoided, but information needed for corrective or emergency actions is not to be suppressed or obscured in satisfying this requirement.

2.14.7 Where information is required by the Rules or by National Administration requirements to be continuously displayed, the system configuration is to be such that the information may be viewed without manual intervention, e.g. the selection of a particular screen page or mode of operation. *See also Pt 16, Ch 1, 2.10 Programmable electronic systems – General requirements 2.10.18* and *Pt 16, Ch 1, 2.10 Programmable electronic systems – General requirements 2.10.19*.

Section 3
Ergonomics of control stations

3.1 Objectives

3.1.1 In order to take account of operator tasks at control stations, enhance usability and reduce human error, the layout arrangements are to comply with the requirements set out in *Pt 16, Ch 1, 3.2 Control station layout*.

3.1.2 In order to establish a working environment that has minimum distractions, is sufficiently comfortable, helps maintain vigilance and maximises communication amongst operators at main control stations, the requirements of *Pt 16, Ch 1, 3.3 Physical environment* are to be complied with.

3.1.3 The requirements of *Pt 16, Ch 1, 3.4 Operator interface* apply to operator interfaces for essential engineering systems located either locally, remotely or within the main control room. The requirements are intended to enhance the usability of systems and equipment, reduce human error, enhance situational awareness and support safe and effective monitoring and control under normal and abnormal modes of operation.

3.2 Control station layout

3.2.1 Control stations are to provide sufficient space and access for the intended number of operators in the expected operating conditions.

3.2.2 Local control stations are to be positioned to minimise the risk of harm to the operator.

3.2.3 Controls, displays and indicators are to be both logically and physically grouped according to their function.

3.2.4 Where a function may be accessed from more than one interface, the arrangement of displays and controls is to be consistent.

3.2.5 Frequently used controls and displays are to be within easy reach and visible to the operator from the normal working position.

3.2.6 Controls and displays used infrequently and which may be used in an emergency are to be clearly identifiable, clearly visible, easily accessible and positioned to allow safe operability.

3.2.7 The relationship of a control with a display is to be immediately apparent.

3.2.8 The relationship of controls and displays with the equipment under control is to be immediately apparent.

3.2.9 There is to be adequate spacing between controls and between controls and obstructions.

3.2.10 Controls and their associated displays are to be located such that the information on the displays can be easily read during the operation of the controls.

3.2.11 Indicators related to the controls are to be visible during their operation.

3.2.12 Instruments are to face the operator's intended working position.

3.3 Physical environment

3.3.1 Control stations are to be positioned, as far as practicable, away from, or insulated against, sources of structurally transmitted vibration and noise, such as ventilation fans, engine intake fans and other noise sources.

3.3.2 In general, noise levels are to comply with IMO Res. MSC.337(91) *Code on Noise Levels On Board Ships*, and are to take into account IMO Res. A.343(IX), *Recommendation on Methods of Measuring Noise; Levels at Listening Posts*.

3.3.3 Where provided, the heating, ventilation and air-conditioning system is to be capable of maintaining the temperature between 18°C and 27°C.

3.3.4 The flow of air from heating or air-conditioning systems is not to be guided directly to the operator, or means are to be provided to adjust the direction of airflow from those systems.

3.3.5 Lighting is to be located to avoid glare from working and display surfaces, and is to be flicker-free. Surfaces are to have a non-reflective or matt finish.

3.3.6 Placement of controls, displays and indicators are to consider the position of light sources relative to the operator with respect to reflections and evenness of lighting.

3.3.7 Where a transparent cover is fitted over a control, display or indicator, it is to be designed to minimise reflections.

3.3.8 The level of lighting is to be sufficient to enable operation of user interfaces. Lighting levels, in accordance with *Table 1.3.1 Specific lighting levels*, will be considered to satisfy this requirement.

Table 1.3.1 Specific lighting levels

Work area	Ideal Lux	Minimum Lux
General lighting	540	220
Control room consoles (front)	540	320
Control room consoles (rear)	325	110
Local operating panels	540	320
Remote operating panels	540	320

3.3.9 Seating provided for use at control stations is to allow for varying height and/or reach needs of operators. Seating arrangements are to minimise the need for twisting and/or turning motions by the operator.

3.3.10 Physical hazards, e.g. sharp edges, protuberances and trip hazards, are to be avoided.

3.3.11 Sufficient handrails or equivalent are to be fitted to enable operators to move and stand safely in rough seas.

3.3.12 Work surfaces are to be capable of withstanding oils and solvents common to ships and are to be easy to clean.

3.4 Operator interface

3.4.1 The design of the operator interface is to permit the satisfactory monitoring, control and supervision of the machinery and equipment.

3.4.2 Information is to be presented to the operator consistently, both within and between different interfaces, *see Pt 16, Ch 1, 3.6 Displays 3.6.2*.

3.4.3 The response of the machinery and equipment to operator input is to be consistent between interfaces for the same function.

3.4.4 Visual, audible or mechanical feedback is to be provided to indicate that operator input has been acknowledged.

3.4.5 Functions requested by the operator are to be confirmed by the displays on completion.

3.4.6 Indications and documentation are to be in English or the language of the crew.

3.5 Controls

3.5.1 Operator inputs are to be checked for errors, for example, out of range data or incorrect actions, and alert the operator when they occur.

3.5.2 Means to rapidly and safely correct wrong inputs or commands is to be provided.

3.5.3 Assistance is to be provided to the operator to recover from operating errors, for example, through advisory screens where the automation system has this facility.

3.5.4 Operator confirmation is to be provided for any control action that could affect the safety of the ship, i.e. they should not rely on single keystrokes.

3.5.5 The purpose of each control is to be clearly indicated. Where standard symbols have been internationally adopted, they should be used.

3.5.6 The settings of mechanical controls are to be immediately evident.

3.5.7 The means of operation of mechanical controls is to be consistent with expectations.

3.5.8 Controls or combined controls and indicators are to be distinguishable from indicators.

3.5.9 Where control is provided by touch screens, the size of the soft keys are to be of a sufficient size for operation in areas where vibration occurs or gloves are likely to be worn.

3.5.10 Where virtual keypads/keyboards or dialogue boxes are used on touch screens, they are not to obscure status or alarm areas of the display.

3.5.11 Keyboards are to be divided logically into functional areas. Alphanumeric, paging and specific keys are to be grouped separately.

3.5.12 Controls that affect the safe operation of the ship should be arranged so as to minimise the possibility of inadvertent operation.

3.6 Displays

3.6.1 The displays and indicators are to present the operator with clear, timely and relevant information.

3.6.2 Graphical symbols and colour coding are to be consistent. The graphical symbols of display functions are to be in accordance with a recognised International Standard, for example, ISO 14617, *Graphical symbols for diagrams* (all parts). Colour coding of functions and signals is to be in accordance with a recognised International Standard, for example, ISO 2412, *Shipbuilding – Colours of indicator lights*.

3.6.3 The symbols used in mimic diagrams for the services listed in *Pt 16, Ch 2, 1.5 Additions or alterations 1.5.1* are to be consistent across all displays.

3.6.4 The display of information is to be consistent with respect to screen layout and arrangement of information.

3.6.5 Flashing of information is to be reserved for unacknowledged alerts, or transient states, for example, valve moving.

3.6.6 The functions supported by a display are to be clearly indicated. For displays that can support multiple functions, it is to be possible to select the display associated with the primary function or an overview by a simple operator action.

3.6.7 The operating mode of the machinery and equipment is to be clearly indicated.

3.6.8 In general, indications provided by instrumentation which are displayed digitally are not to change more frequently than twice per second.

3.6.9 To indicate an increasing value in a single direction, on a fixed circular scale, the pointer is to move clockwise. If the pointer is fixed, the scale is to move anticlockwise to indicate an increase in value.

3.6.10 To indicate an increasing value on a horizontal linear scale, the pointer is to move from left to right. On a vertical linear scale, the pointer is to move upwards to indicate an increase in value.

3.6.11 The pointer is not to obscure the numbers on the scale.

3.6.12 Alphanumeric data, text, symbols and other graphical information is to be readable from relevant operator positions under lighting conditions as specified in *Pt 16, Ch 1, 3.3 Physical environment 3.3.8*. Character height in millimetres is to be not less than three and a half times the reading distance in metres and the character width is to be 0,7 times the character height.

3.6.13 A simple sans-serif character font is to be used in displays. In descriptive text, lower case letters are to be used, where appropriate, as opposed to capitals to improve readability.

3.6.14 Where information related to the safe operation of machinery and equipment is provided, it is to be continuously available to the operator.

3.6.15 Failures are to be indicated in a clear and unambiguous manner. Sufficient information is to be provided for the operator to identify the cause of the failure.

■ *Section 4*
Unattended machinery space(s) - UMS notation

4.1 General

4.1.1 Where it is proposed to operate the following machinery in an unattended space, no matter what period is envisaged, the controls, alarms and safeguards required by the appropriate Chapters together with those given in *Pt 16, Ch 1, 4.2 Alarm system for machinery* are to be provided:

- Air compressors.
- Controllable pitch propellers.
- Electric generating plant.
- Fuel oil transfer and storage systems.
- Propulsion machinery including essential auxiliaries.
- Steam raising plant (boilers and their ancillary equipment).
- Thermal fluid heaters.

4.2 Alarm system for machinery

4.2.1 An alarm system which will provide warning of faults in the machinery is to be installed. The system is to satisfy the requirements of*Pt 16, Ch 1, 2.3 Alarm systems*.

4.2.2 Audible and visual indication of machinery alarms is to be relayed to the engineers' accommodation so that engineering personnel are made aware that a fault has occurred.

4.2.3 The engineers' alarm required by *Pt 16, Ch 1, 2.2 Control stations for machinery 2.2.4* is to be activated automatically in the event that a machinery alarm or warning has not been acknowledged in the space within a predetermined time.

4.2.4 Audible and visual indication of machinery alarms is to be relayed to the navigating bridge control station in such a way that the navigating officer of the watch is made aware when:

(a) a machinery fault has occurred,
(b) the machinery fault is being attended to, and
(c) the machinery fault has been rectified.

4.2.5 Group alarms may be arranged on the bridge to indicate machinery faults, but alarms associated with faults requiring speed or power reduction or the automatic shutdown of propulsion machinery are to be identified by separate group alarms or by individual alarm parameters.

4.3 Bridge control for propulsion machinery

4.3.1 A bridge control system for the propulsion machinery is to be fitted. The system is to satisfy the requirements of *Pt 16, Ch 1, 2.6 Bridge control for propulsion machinery*.

4.4 Control stations for machinery

4.4.1 A control station(s) is to be provided in the space and on the bridge which satisfies the requirements of *Pt 16, Ch 1, 2.2 Control stations for machinery*.

4.5 Fire detection alarm system

4.5.1 . An automatic fire detection system is to be fitted in the space together with an audible and visual alarm system. The system is to satisfy the requirements of*Pt 16, Ch 1, 2.8 Fire detection and fire alarm systems*.

4.6 Fixed water-based local application fire-fighting systems

4.6.1 Where fixed water-based local application fire-fighting systems are installed, they are to satisfy the requirements of *Pt 16, Ch 1, 2.9 Fixed water-based local application fire-fighting systems*.

4.6.2 Fixed water-based local application fire-fighting systems are to be capable of automatic release in accordance with *SOLAS - International Convention for the Safety of Life at Sea*, *Chapter II-2 - Construction - Fire protection, fire detection and fire extinction*, *Part C - Suppression of fire*,*Regulation 10 - Fire fighting*.

4.7 Bilge level detection

4.7.1 An alarm system is to be provided to warn when liquid in machinery space bilges has reached a predetermined level, and is to comply with *Pt 16, Ch 1, 2.3 Alarm systems*. This level is to be sufficiently low to prevent liquid from overflowing from the bilges onto the tank top. The number and location of detectors are to be such that accumulation of liquids will be detected at all angles of heel and trim.

4.7.2 Local or remote controls of any valve within the space serving a sea inlet, a discharge below the waterline, a bilge injection or a direct bilge system, should be so sited as to be readily accessible and to allow adequate time for operation in case of influx of water to the space, having regard to the time which could be taken to reach and operate such controls, *see also Pt 16, Ch 1, 2.7 Valve control systems* and *Pt 15, Ch 2, 2 Construction and installation* and *Pt 15, Ch 2, 4 Bilge pumping and drainage systems*.

4.7.3 Where the bilge pumps are arranged to start automatically, means are to be provided to indicate if the influx of liquids is greater than the pump capacity or, if the pump is operating more frequently than would be expected. Special attention should be given to oil pollution prevention requirements.

4.8 Supply of electric power, general

4.8.1 For craft operating with one generator set in service, arrangements are to be such that a standby generator will automatically start and connect to the switchboard in as short a time as practicable, but in any case within 45 seconds, on loss of the service generator. For craft operating with two or more generator sets in service, arrangements are to be such that on loss of one generator the remaining one(s) are to be adequate for continuity of essential services. For the detailed requirements of these arrangements, *see Pt 16, Ch 2, 2.2 Number and rating of generators and converting equipment*.

■ *Section 5*
Machinery operated from a centralised control station - CCS notation

5.1 General requirements

5.1.1 Where it is proposed to operate the machinery as listed in *Pt 16, Ch 1, 4.1 General 4.1.1* with continuous supervision from a centralised control station, the control station is to be such that the machinery operation will be as effective as it would be under direct supervision.

5.1.2 The arrangements are to be such that corrective actions can be taken at the control station in the event of machinery faults, e.g. stopping of machinery, starting of standby machinery, adjustment of operating parameters, etc. These actions may be effected by either remote manual or automatic control.

5.1.3 The controls, alarms and safeguards required by the appropriate Chapters and by *Pt 16, Ch 1, 4.7 Bilge level detection* together with a fire detection system satisfying the requirements of *Pt 16, Ch 1, 2.8 Fire detection and fire alarm systems* are to be provided.

5.1.4 Additional requirements for controls, alarms and safeguards are given in *Pt 16, Ch 1, 5.2 Centralised control station for machinery*.

5.2 Centralised control station for machinery

5.2.1 A centralised control station is to be provided at some suitable location, which satisfies the requirements of *Pt 16, Ch 1, 5.2 Centralised control station for machinery 5.2.2*.

5.2.2 A system of alarm displays and controls is to be provided which readily ensures identification of faults in the machinery and satisfactory supervision of related equipment. The alarm and control systems are to satisfy the requirements of *Pt 16, Ch 1, 2.3 Alarm systems* and *Pt 16, Ch 1, 2.5 Control systems*, as applicable.

5.2.3 Indication of all essential parameters necessary for the safe and effective operation of the machinery is to be provided, e.g. temperatures, pressures, tank levels, speeds, powers, etc.

5.2.4 Indication of the operational status of running and standby machinery is to be provided.

5.2.5 At the centralised control station, means of communication with the bridge area, the accommodation for engineering personnel and, if necessary, the machinery space are to be provided.

5.2.6 In addition to the communication required by *Pt 16, Ch 1, 5.2 Centralised control station for machinery 5.2.5*, a second means of communication is to be provided between the bridge and the centralised control station. One of these means is to be independent of the main electrical power supply.

5.2.7 Arrangements are to be provided in the centralised control station so that the normal supply of electrical power may be restored in the event of failure.

■ *Section 6*
Requirements for craft which are not required to comply with the HSC Code

6.1 General

6.1.1 The relevant requirements of *Pt 16, Ch 1, 1 General requirements* and *Pt 16, Ch 1, 2 Essential features for control, alarm, monitoring and safety systems* are to be complied with.

6.1.2 For vessels which are to be assigned or to be eligible for the **UMS** or **CCS** notations the requirements of *Pt 16, Ch 1, 4 Unattended machinery space(s) - UMS notation* and *Pt 16, Ch 1, 5 Machinery operated from a centralised control station - CCS notation* are to be complied with.

6.1.3 For yachts less than 500 gt and small craft not requiring the **UMS** and **CCS** notation, the requirements of *Pt 16, Ch 1, 6.2 Plans and information* and *Pt 16, Ch 1, 6.3 Control and supervision of unattended machinery* apply.

6.1.4 Yachts that are 500 gt or more are to comply with the requirements of *Pt 16, Ch 1, 1 General requirements* and *Pt 16, Ch 1, 2 Essential features for control, alarm, monitoring and safety systems*.

6.2 Plans and information

6.2.1 Plans are required to be submitted in accordance with *Pt 16, Ch 1, 1.2 Documentation required for design review* only for the machinery items applicable to these craft.

6.3 Control and supervision of unattended machinery

6.3.1 Where machinery items applicable to these craft are fitted with automatic or remote controls so that under normal operating conditions they do not require any manual intervention by the operators they are to be provided with the alarms and safety arrangements specified in the appropriate Chapters of the Rules.

■ *Section 7*
Trials

7.1 General

7.1.1 Before a new installation (or any alteration or addition to an existing installation) is put into service, trials are to be carried out. These trials are in addition to any acceptance tests which may have been carried out at the manufacturers' works and are to be based on the approved test schedules list as required by *Pt 16, Ch 1, 1.2 Documentation required for design review 1.2.3*. In the case of new construction it will be expected that most of these trials will be carried out before the official sea trials of the craft. During sea trials, system dynamic tests are to be carried out to demonstrate overall satisfactory performance of the control engineering installation.

7.1.2 Means are to be provided to facilitate testing during normal machinery operation, e.g. by the provision of three-way test valves or equivalent.

7.1.3 Acceptance tests and trials for Programmable Electronic Systems are to include verification of software lifecycle activities appropriate to the stage in the system's lifecycle at the time of system examination. The documentation required by *Pt*

16, Ch 1, 1.2 Documentation required for design review 1.2.6 is to be in accordance with the current configuration and the testing and trials are to address software modifications and configuration management procedures to the Surveyor's satisfaction.

7.1.4 Wireless data communication links are to be operational and tested during trials. Tests are to demonstrate that radio-frequency transmission does not interfere with the operation of equipment required by this Chapter or other Sections of the Rules and does not itself malfunction as a result of electromagnetic interference during expected operating conditions. Reversionary modes are to be activated to demonstrate continued safe and effective operation in the event of fault conditions.

7.1.5 Before installation of programmable electronic systems programs, data and the physical medium used for installation on the vessel are to be scanned for viruses and malicious software. Results of the scan are to be documented, kept with the software registry and be available to the Surveyor on request.

7.2 Unattended machinery space operation - UMS notation

7.2.1 In addition to the tests required by *Pt 16, Ch 1, 7.1 General*, the suitability of the installation for operation in the unattended mode is to be demonstrated during sea trials observing the following:

(a) Occurring alarms and the frequency of operation both during steady steaming and under manoeuvring conditions using bridge control.
(b) Any intervention by personnel in the operation of the machinery.

7.3 Operation from a centralised control station - CCS notation

7.3.1 In addition to the tests required by *Pt 16, Ch 1, 7.1 General*, the suitability of the installation for operation from the centralised control station is to be demonstrated during sea trials.

7.4 Record of trials

7.4.1 Two copies of the alarm and control equipment test schedules, as required by *Pt 16, Ch 1, 1.2 Documentation required for design review 1.2.3*, signed by the Surveyor and Builder are to be provided on completion of the survey. One copy is to be placed on board the vessel and the other submitted to LR.

■ *Section 1* General requirements

1.1 General

1.1.1 The requirements of *Pt 16, Ch 2, 1 General requirements* and *Pt 16, Ch 2, 21 Testing and trials* are, in general, applicable to all the craft types indicated in *Pt 1, Ch 2, 2.1 Applicable craft types*, with the exception of cargo craft, patrol and pilot craft, workboats and other similar craft of less than 500 tons gross tonnage for operation in Service Groups 1 to 3, and for yachts less than 500 gt, which are covered in *Pt 16, Ch 2, 20 Cargo craft, patrol and pilot craft, workboats and other similar craft of less than 500 tons gross tonnage for operation in Service Groups 1 to 3, and yachts less than 500 gt*.

1.1.2 Whilst this Chapter applies to the electrical engineering equipment and systems on special service craft intended to be classed, attention should also be given to any relevant Statutory Regulations of the National Authority of the country in which the craft is to be registered and the Code of Safety for High Speed Craft.

1.1.3 Electrical services required to maintain the craft in a normal seagoing, operational and habitable condition are to be capable of being maintained without recourse to the emergency source of electrical power.

1.1.4 Electrical services essential for safety are to be maintained under declared normal and reasonably foreseeable abnormal conditions.

1.1.5 The safety of passengers, crew and craft from electrical hazards is to be ensured.

1.1.6 Consideration will be given to special cases or to arrangements which are equivalent to the Rules.

1.2 Documentation required for design review

1.2.1 The documentation described in *Pt 16, Ch 2, 1.2 Documentation required for design review 1.2.2* to *Pt 16, Ch 2, 1.2 Documentation required for design review 1.2.13* is to be submitted for design review.

1.2.2 Single line diagrams of main, emergency and transitional power and lighting systems which are to include:

(a) ratings of machines, transformers, batteries and semiconductor converters;
(b) all feeders connected to the main and emergency switchboards;
(c) section boards and distribution boards;
(d) insulation type, size and current loadings of cables;
(e) make, type and rating of circuit breakers and fuses;
(f) details of harmonic filters (where fitted); and
(g) details of power supply arrangements used for control systems.

1.2.3 A functional description of operation of the main, emergency and transitional electrical power systems, which is to include:

(a) the operating philosophy of the main, emergency and transitional electrical power systems under normal and reasonably foreseeable abnormal conditions:
(b) degraded modes of operation;
(c) load management and load sharing philosophy; and
(d) protection philosophy.

1.2.4 An earthing philosophy document that defines the basic approach to be taken for earthing the electrical power systems and all electrical loads.

1.2.5 Simplified diagrams of generator circuits, inter-connector circuits and feeder circuits showing:

(a) protective devices, e.g. short circuit, overload, reverse power protection;
(b) instrumentation and synchronising devices;
(c) preference tripping;
(d) remote stops and fire safety stops; and
(e) earth fault indication/protection.

1.2.6 Calculations of short circuit currents at main, emergency and transitional switchboards and section boards, including those fed from transformers, with details of circuit breaker and fuse operating times and discrimination curves showing compliance with *Pt 16, Ch 2, 6.1 General* and *Pt 16, Ch 2, 11.6 Conductor size 11.6.2*.

1.2.7 Where required by *Pt 16, Ch 2, 8.1 General 8.1.1*, the hazards resulting from electric arcs within electrical equipment and their consequences for personnel are to be identified, and at least the following supporting evidence is to be submitted:

(a) system design;
(b) operating philosophies, e.g. manual or automatic control, local or remote operation;
(c) general arrangement plans for switchboards, section boards and distribution boards, *see also Pt 16, Ch 2, 1.3 Documentation required for supporting evidence 1.3.5*;
(d) general arrangement plans for the space in which the electrical equipment to be assessed are located, showing:
    (i) access to adjacent spaces;
    (ii) the location of the electrical equipment;

- (iii) ventilation arrangements for air-conditioning and/or the extraction of smoke, gas and vapours resulting from electric arcs; and
- (iv) positions within the space in which the electrical equipment is located where personnel will be performing tasks, e.g. switching, equipment maintenance, instrument observation or cleaning, or where personnel could be reasonably expected to enter;

(e) calculations in accordance with *Pt 16, Ch 2, 8.3 Calculations to be submitted*;

(f) system operating procedures; and

(g) details of defined additional safety measures to be taken during activities.

1.2.8 For battery installations, arrangement plans and calculations to show compliance with *Pt 16, Ch 2, 12 Batteries*.

1.2.9 A schedule of batteries fitted for use for emergency and essential services, giving details of:

- type and manufacturer's type designation;
- voltage and ampere-hour rating;
- location;
- equipment and/or system(s) served;
- maintenance/replacement cycle dates;
- date(s) of maintenance and/or replacement; and
- for replacement batteries in storage, the date of manufacture and shelf life, with accompanying battery replacement procedure documentation to show compliance with *Pt 16, Ch 2, 12.7 Recording of batteries for emergency and essential services*.

Note The above includes all batteries fitted as part of an uninterruptible power system (UPS) used for any essential or emergency services.

1.2.10 Details of electrically-operated fire, craft, crew and passenger emergency safety systems which are to include typical single line diagrams and arrangements, showing main vertical and, where applicable, horizontal fire zones and the location of equipment and cable routes, including identification of relevant high fire risk areas, to be employed for:

(a) emergency lighting;

(b) accommodation fire detection, alarm and extinction systems;

(c) Fixed water-based local application fire-fighting systems;

(d) public address system;

(e) general emergency alarm;

(f) watertight doors, shell doors and other electrically operated closing appliances; and

(g) low location lighting.

Note A general arrangement plan of the complete craft showing the main vertical fire zones and the location of equipment and cable routes, including identification of relevant high fire risk areas, for the above systems, is to be made available for the use of the Surveyor on board.

1.2.11 Evidence of the suitability of electrical and electronic equipment for use in protected areas and adjacent areas, as required by *Pt 16, Ch 2, 17.3 Fixed water-based local application fire-fighting systems 17.3.9* and *Pt 16, Ch 2, 17.3 Fixed water-based local application fire-fighting systems 17.3.10*, including a schedule of electrical and electronic equipment located in protected areas and adjacent areas, and general arrangement plans showing the coverage of the protected areas and adjacent areas. *See also Pt 16, Ch 2, 1.11 Location and construction*.

1.2.12 Schedule of normal and emergency operating loads on the system estimated for the different operating conditions expected. The following details are to be provided to meet this requirement:

(a) a description of the expected operating profiles (e.g. the number of generating sets connected when manoeuvring, at sea, etc.), including as required by *Pt 5, Ch 2, 1.1 General 1.1.1*; and

(b) a schedule of the normal and emergency operating loads, which is to state the kilowatt rating of each load and a load factor between 0 and 1 that reflects:

- (i) the duty cycle of the load; and
- (ii) the proportion of its maximum rating at which the load is expected to operate.

1.2.13 **Lithium battery systems**. In addition to the plans and information required by *Pt 16, Ch 1, 1.2 Documentation required for design review 1.2.2*, the following information is also to be submitted:

(a) System functional description including all operating modes (i.e. charging, discharging, standby, backup, peak shaving, etc.), safety functions and their hierarchy and expected battery system behaviour in case of malfunction.
(b) Technical description detailing how safety information from type testing has been considered in the actual installation design.
(c) Integration plan for the battery system with the vessel power distribution and charging arrangements.
(d) Line diagrams of the battery system control and power distribution, including switchgear, protective devices, controlgear and emergency trip (E-Trip) as well as interfaces to external systems.
(e) A Failure Mode and Effects Analysis (FMEA) and mitigation strategy is to be carried out for the lithium battery system installation as a whole in accordance with IEC 60812*: Analysis techniques for system reliability – Procedure for failure mode and effects analysis (FMEA)*, or an equivalent and acceptable National or International Standard and the report and worksheets are to be submitted for consideration.
(f) Arrangement plans of any HVAC, ventilation, cooling system and drains for the battery space.
(g) Fire detection, alarm and extinguishing system (including portable fire-fighting appliances) plans for the battery space.
(h) A schedule of electrical equipment for use in the battery space and HVAC, ventilation and cooling systemgiving details of the appropriate type of protection for the temperature class and gas group of the potential gases. Copies of appropriate certification are to be submitted for consideration.
(i) Arrangement plans for electrical equipment showing cable routes associated with the battery system, power distribution and E-Trip.
(j) General arrangement plan showing hazardous zones for the battery space, including the HVAC, ventilation, cooling system and drains.
(k) Fire integrity plans for the battery space (including penetration drawings), contiguous spaces and means of escape from the battery space.

1.2.14 For ships with hybrid electrical power systems as detailed in *Pt 16, Ch 2, 23 Hybrid electrical power systems* the following documentation is to be submitted for design review either uniquely or integrated with other submitted information:

Information required for all hybrid electrical power systems:

(a) A functional description of the electrical distribution systems and equipment that details compliance with the performance criteria and system capability and functionality under defined normal and reasonably foreseeable abnormal conditions including:
    (i) degraded modes of operation;
    (ii) load management and load sharing philosophy;
    (iii) earthing philosophy;
    (iv) system electrical protection philosophy;
    (v) system stability; and
    (vi) converter switching actions.
(b) Definition of system performance targets (*see Pt 16, Ch 2, 23.5 Hybrid electrical power system performance - System performance targets*);
(c) Definition of dependability principles (*see Pt 16, Ch 2, 23.6 Hybrid electrical power system performance - Dependability principles*);
(d) Calculations supporting the size and rating of stores of electrical energy (*see Pt 16, Ch 2, 23.6 Hybrid electrical power system performance - Dependability principles 23.6.7*);
(e) Risk assessment in support of there being no dedicated emergency source of power when this is proposed (*see Pt 16, Ch 2, 23.8 Hybrid electrical power system performance - Emergency source of electrical power 23.8.2*);
(f) Details of any arrangements for external sources of power to charge onboard stores of electrical energy (*see Pt 16, Ch 2, 23.9 Hybrid electrical power system performance - External source of electrical power 23.9.3*);
(g) Voltage rate of rise times for pulse width modulated converters (*see Pt 16, Ch 2, 23.11 Hybrid electrical power system components - Source of electrical power 23.11.6*);
(h) Risk assessment in support of active fault current limiting devices when this is proposed (*see Pt 16, Ch 2, 23.15 Hybrid electrical power system components - Distribution system 23.15.11*);
(i) Technical description of energy management functionality (*see Pt 16, Ch 2, 23.16 Hybrid electrical power system components - Energy management 23.16.4* and *Pt 16, Ch 2, 23.16 Hybrid electrical power system components - Energy management 23.16.7*);
(j) Technical description of arrangements for power quality monitoring (*see Pt 16, Ch 2, 23.17 Transversal requirements 23.17.6*);

(k) Power system integration procedure (*see Pt 16, Ch 2, 23.18 Power system development and integration - General*);

(l) System operational concept (*see Pt 16, Ch 2, 23.19 Power system development and integration - System operational concept*);

(m) Technical description of operating modes (*see Pt 16, Ch 2, 23.20 Power system development and integration - Operating modes*);

(n) Validated specifications of system components (*see Pt 16, Ch 2, 23.22 Power system development and integration - System components*);

(o) Results of energy flow analysis (*see Pt 16, Ch 2, 23.23 Power system development and integration - Energy flows*);

(p) Results of power system analysis (*see Pt 16, Ch 2, 23.24 Power system development and integration - Power system analysis*);

(q) Definition of safety functions (*see Pt 16, Ch 2, 23.25 Power system development and integration - Safety functions*);

(r) System FMEA (*see Pt 16, Ch 2, 23.27 Power system development and integration - System Failure Modes and Effects Analysis (FMEA)*);

(s) System operating instructions (*see Pt 16, Ch 2, 23.28 Power system development and integration - Operating instructions*);

(t) Description and verification of ship-specific Operator training needs (*see Pt 16, Ch 2, 23.29 Power system development and integration - Operator training*); and

(u) Description of through-life system integration roles and responsibilities (*see Pt 16, Ch 2, 23.30 Power system development and integration - Through-life accountability*).

Additional information required for Hybrid Power (+) notation systems:

(a) Dependability assessment (*see Pt 16, Ch 2, 23.6 Hybrid electrical power system performance - Dependability principles*);

(b) Technical description of arrangements for automatic earth fault location (*see Pt 16, Ch 2, 23.15 Hybrid electrical power system components - Distribution system 23.15.16*);

(c) Technical description of arrangements for power quality degradation detection (*see Pt 16, Ch 2, 23.15 Hybrid electrical power system components - Distribution system 23.15.23*);

(d) Technical description of additional energy management functionality (*see Pt 16, Ch 2, 23.16 Hybrid electrical power system components - Energy management 23.16.8*);

(e) Validation, verification and results of energy flow simulation (*see Pt 16, Ch 2, 23.23 Power system development and integration - Energy flows 23.23.3*);

(f) Validation, verification and results of power system simulation (*see Pt 16, Ch 2, 23.24 Power system development and integration - Power system analysis 23.24.4*);

(g) Risk assessment study when required (*see Pt 16, Ch 2, 23.26 Power system development and integration - Risk assessment*); and

(h) Evidence of ship-specific Operator training verification (*see Pt 16, Ch 2, 23.29 Power system development and integration - Operator training 23.29.2*).

1.3 Documentation required for supporting evidence

1.3.1 The documentation and particulars in *Pt 16, Ch 2, 1.3 Documentation required for supporting evidence 1.3.2* to *Pt 16, Ch 2, 1.3 Documentation required for supporting evidence 1.3.7* are to be submitted as supporting evidence.

1.3.2 In order to establish compliance with *Pt 16, Ch 2, 1.11 Location and construction 1.11.2* and *Pt 16, Ch 2, 5.1 Systems of supply and distribution 5.1.3* to *Pt 16, Ch 2, 5.1 Systems of supply and distribution 5.1.5*, a general arrangement plan of the craft showing the location of major items of electrical equipment, for example:

- main and emergency generators;
- transitional source of supply (where fitted);
- switchboards;
- section boards and distribution boards supplying essential and emergency services;
- emergency batteries;
- motors for emergency services; and
- cable routes between these items of equipment.

1.3.3 Arrangement plans of main and emergency switchboards, and section boards, and documentation that demonstrates that creepage and clearance distances are in accordance with *Pt 16, Ch 2, 7.5 Creepage and clearance distances*. The form factor of internal separation of low voltage switchgear and controlgear assemblies is to be in accordance with IEC 61439-2: *Low-voltage switchgear and controlgear assemblies — Part 2: Power switchgear and controlgear assemblies*, or an alternative

acceptable and relevant National Standard. The form factor is to be stated, and the arrangement plans are to show how the forms have been achieved.

1.3.4 In order to establish compliance with the requirements of *Pt 16, Ch 2, 1.7 Design and construction 1.7.3*, when requested, evidence is to be submitted to demonstrate the suitability of electrical equipment for its intended purpose in the conditions in which it is expected to operate.

1.3.5 For non-metallic cable support systems or protective casings, test evidence, details of installation procedures and manufacturer's recommendations that show compliance with *Pt 16, Ch 2, 11.13 Non-metallic cable support systems, protective casings and fixings*.

1.3.6 Details of, and arrangements in, the spaces in which the lighting is required to satisfy the requirements of *Pt 16, Ch 2, 22 Ergonomic Lighting Design – ELD optional notation* Ergonomic Lighting Design (EDL) optional notation.

1.3.7 **Lithium battery systems**. In addition to the plans and information required by *Pt 16, Ch 2, 1.2 Documentation required for design review 1.2.13*, the following information is also to be submitted:

(a) Document outlining the operational limitations for the battery system.
(b) Operation, maintenance and training manuals for the battery system are to be kept on board including:
    (i) Manual that describes the standard operating, maintenance and emergency procedures for the system;
    (ii) Testing procedures including Annual Survey test requirements (*see Table 2.21.2 Test requirements on lithium battery systems*);
    (iii) Through-life management plan for the battery system, including disposal.

1.4 Surveys

1.4.1 Electrical machinery and auxiliary services essential for the safety of the craft are to be installed in accordance with the relevant requirements of this Chapter, surveyed and have tests witnessed by the Surveyors.

1.4.2 The following equipment, where intended for use for essential and emergency services, is to be surveyed by the Surveyors during manufacture and testing:

- Converting equipment of 100 kW and over;
- Rotating machines of 100 kW and over;
- Switchboards and section boards; and
- UPS units of 50 kVA and over.

1.4.3 For electric propulsion systems, in addition to the equipment listed in *Pt 16, Ch 2, 1.4 Surveys 1.4.2*, the following equipment is to be surveyed by the Surveyors during manufacture and testing:

- exciters;
- filters;
- reactors;
- dynamic braking assemblies;
- pre-magnetisation transformers; and
- slip ring assemblies.

1.4.4 All other electrical equipment, not specifically referenced in *Pt 16, Ch 2, 1.4 Surveys 1.4.2* and *Pt 16, Ch 2, 1.4 Surveys 1.4.3*, intended for use for essential or emergency services is to be supplied with a manufacturer's works test certificate showing compliance with the constructional standard(s) as referenced by the relevant requirements of this Chapter.

1.4.5 Alternative approach for product assurance;

(a) LR will be prepared to give consideration to the adoption of an approach for product assurance, utilising regular and systematic audits of an organisation's arrangements for assuring product quality, as an alternative to the direct survey of individual items.
(b) Alternative approaches for product assurance are to be approved by LR. In order to obtain approval, the requirements of *Pt 5, Ch 1, 6 Quality Assurance Scheme for Machinery* of the *Rules and Regulations for the Classification of Ships, July 2021* or *Ch 1, 2.4 Materials Quality Scheme* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2021* are to be complied with. Proposals for equivalent approaches are to be submitted for consideration.

1.5 Additions or alterations

1.5.1 No addition, temporary or permanent, is to be made to the approved load of an existing installation until it has been ascertained that the current carrying capacity and the condition of the existing equipment including cables and switchgear are adequate for the increased load.

1.5.2 Plans are to be submitted for consideration, and the alterations or additions are to be carried out under the survey, and to the satisfaction of the Surveyors.

1.5.3 When it is proposed to replace permanently installed secondary valve-regulated sealed batteries with vented batteries, details are to be submitted for consideration to ensure continued safety in the presence of the products of electrolysis and evaporation being allowed to escape freely from the cells to the atmosphere. These details are to demonstrate that there will be adequate ventilation in accordance with *Pt 16, Ch 2, 12.5 Thermal management and ventilation 12.5.9* and that the location and installation requirements of *Pt 16, Ch 2, 12.3 Location* and *Pt 16, Ch 2, 12.4 Installation* are complied with.

1.5.4 Proposed modifications to the electrical protection systems are to be developed in accordance with *Pt 16, Ch 2, 6.1 General 6.1.4* and plans submitted are also to address the updating of approved version of the details required by *Pt 16, Ch 2, 1.2 Documentation required for design review 1.2.5* and *Pt 16, Ch 2, 1.2 Documentation required for design review 1.2.6*.

1.5.5 Where it is intended to replace an existing incandescent lamp type navigation light with a light emitting diode type navigation light, details are to be submitted for consideration that demonstrate compliance with *Pt 16, Ch 2, 15.3 Navigation lights*. Light emitting diode type navigation light failure detection arrangements are to satisfy the requirements of *Pt 16, Ch 2, 15.3 Navigation lights 15.3.5* and *Pt 16, Ch 2, 15.3 Navigation lights 15.3.6*.

1.6 Definitions

1.6.1 Essential services are those necessary for the propulsion and safety of the craft, such as the following:

- air compressors for starting and manoeuvring essential mains and auxiliary machinery;
- air pumps;
- automatic sprinkler systems;
- ballast pumps;
- bilge pumps;
- circulating and cooling water pumps;
- communication systems;
- electric starting systems for starting and manoeuvring essential main and auxilliary machinery;
- fire detection and alarm systems;
- fire pumps;
- fuel valve cooling pumps;
- hydraulic pumps for controllable pitch propellers and those serving essential services here listed that would otherwise be directly electrically-driven;
- hydraulic pumps serving essential services here listed which would otherwise be directly electrically driven;
- lubricating oil pumps;
- lighting systems for those parts of the craft normally accessible to and used by personnel and passengers;
- navigational aids where required by Statutory Regulations;
- navigation lights and special purpose lights where required by Statutory regulations;
- fuel oil pumps and fuel oil burning units;
- pumps for fire-extinguishing systems;
- scavenge blowers;
- steering gear;
- Thrusters needed for the propulsion and safety of the ship to be considered as essential services;
- valves which are required to be remotely operated;
- ventilating fans for engine rooms;
- watertight doors, shell doors and other electrical operated closing appliances;
- windlasses;
- power sources and supply systems for supplying the above services.

1.6.2 Services such as the following are considered necessary for minimum comfortable conditions of habitability:

- cooking;
- heating;
- domestic refrigeration;
- mechanical ventilation;
- sanitary and fresh water.

1.6.3 Services such as the following, which are additional to those in *Pt 16, Ch 2, 1.6 Definitions 1.6.1* and *Pt 16, Ch 2, 1.6 Definitions 1.6.2*, are considered necessary to maintain the craft in a normal seagoing operational and habitable condition:

- cargo handling and cargo care equipment;
- hotel services, other than those required for habitable conditions;
- thruster systems for manoeuvring.

1.6.4 A `high voltage' is a voltage exceeding 1000 V a.c. or 1500 V d.c. between conductors, *see also Pt 16, Ch 2, 5.1 Systems of supply and distribution 5.1.2*.

1.6.5 A `switchboard' is a switchgear and controlgear assembly for the control of power generated by a source of electrical power and its distribution to electrical consumers.

1.6.6 A `section board' is a switchgear and controlgear assembly for controlling the supply of electrical power from a switchboard and distributing it to other section boards, distribution boards or final sub-circuits.

1.6.7 A `distribution board' is an assembly of one or more protective devices arranged for the distribution of electrical power to final sub-circuits.

1.6.8 A `final sub-circuit' is that portion of a wiring system extending beyond the final overcurrent device of a board.

1.6.9 `Special Category spaces' are those enclosed spaces above or below the bulkhead deck intended for the carriage of motor vehicles with fuel, for their own propulsion, in their tanks, into and from which such vehicles can be driven, and to which passengers have access.

1.6.10 'Machinery spaces of Category A' are those spaces and trunks to such spaces which contain:

(a) internal combustion machinery used for main propulsion; or
(b) internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 kW; or
(c) any oil-fired boiler or fuel oil unit.

1.6.11 `Dead craft condition' means that the entire machinery installation, including the power supply, is out of operation and that the auxiliary services for bringing the main propulsion systems into operation (e.g. compressed air, starting current from batteries, etc.) and for the restoration of the main power supply are not available. Means are to be available at all times to start the emergency generator, *see Pt 10, Ch 1, 9.5 Starting of the emergency source of power*.

1.6.12 Protected space is a machinery space where a fixed water-based local application fire-fighting system is installed.

1.6.13 Protected areas are areas within a protected space which is required to be protected by a fixed water-based local application fire-fighting system.

1.6.14 Adjacent areas are areas, other than protected areas, exposed to direct spray or other areas where water may extend when a fixed water-based local application fire-fighting system is activated.

1.6.15 An ‘electric arc’ is an electrical discharge or a short-circuit through ionised air caused by isolation or insulation integrity failure.

1.6.16 ‘Incident energy’ is the amount of energy impressed on a surface, a certain distance from the source, generated during an electric arc event.

1.6.17 A ‘secondary lithium cell’ is a cell where electrical energy is derived from the insertion/extraction reactions of lithium ions or oxidation/reduction of lithium between the negative electrode and the positive electrode. These may be combined in ‘cell blocks’ consisting of a group of cells connected together in a parallel configuration.

1.6.18 A ‘battery module’ is an energy storage device comprising one or more electrically connected cells or cell blocks. The battery module can include protective and monitoring devices.

1.6.19 A ‘battery pack’ is an energy storage device comprising one or more electrically connected cells, cell blocks or modules. The battery pack can include protective devices and control and monitoring systems which communicate with the battery management system.

1.6.20 A 'battery management system (BMS)' is an electronic system which monitors and manages the state of a cell, battery module or battery pack in order to maintain the battery system in a safe operating state and protect against overcharging, overcurrent and overheating and communicates with an external charge/discharger controller.

1.6.21 A 'lithium battery system' is a system comprising one or more lithium battery modules or packs incorporated in a fixed installation together with means of isolation, a cooling system (if provided) and has an associated BMS.

1.6.22 'State of charge (SOC)' is the available capacity in a battery expressed as a percentage of rated capacity.

1.6.23 'State of health (SOH)' reflects the general condition of a battery expressed as a percentage of its ability to deliver the specified performance compared with that of a new battery.

1.6.24 'Battery space' is the space or compartment in which a battery is installed.

1.7 Design and construction

1.7.1 Equipment for services essential for the safety of the craft are to be constructed in accordance with the relevant requirements of this Chapter.

1.7.2 The design and installation of other equipment is to be such that risk of fire due to its failure is minimised. It is to, as a minimum, comply with a National or International Standard revised where necessary for ambient conditions.

1.7.3 Electrical equipment is to be suitable for its intended purpose and accordingly, whenever practicable to be selected from the List of Type Approved Products published by Lloyd's Register's (hereinafter referred to as 'LR'). A copy of the Procedure for LR Type Approval System will be supplied on application.

1.7.4 Permanently installed electrical and electronic equipment that are capable of generating electromagnetic interference, which can interfere with the proper functionality of essential services or services upon which they depend, are to be designed, constructed and installed in accordance with the guidelines and recommendations of one of the following standard(s), as appropriate to its location:

(a) IEC 60533 - *Electrical and electronic installations in ships - Electromagnetic compatibility (EMC)*; or
(b) IEC 60945 - *Maritime navigation and radiocommunication equipment and systems – General requirements – Methods of testing and required test results*; or
(c) LR Type Approval System – Test Specification Number 1;
(d) Alternative national or international standard(s) acceptable to LR.

1.7.5 For areas susceptible to deluge or submersion, cable entries are to prevent water ingress. In general, cable entries are to be in accordance with IEC 60092-101: *Electrical Installations in Ships – Part 101: Definitions and General Requirements*.

1.8 Quality of power supplies

1.8.1 All electrical equipment supplied from the main and emergency sources of electrical power and electrical equipment for essential and emergency services supplied from d.c. sources of electrical power is to be so designed and manufactured that it is capable of operating satisfactorily under normally occurring variations of voltage and frequency.

1.8.2 Unless specified otherwise, a.c. electrical equipment is to operate satisfactorily with the following simultaneous variations, from their nominal value, when measured at the consumer input terminals. Alarms are to be provided for High and Low Voltage and Low Frequency.

(a) Voltage:

- permanent variations +6 per cent, -10 per cent
- transient variations due to step changes in load ±20 per cent
- recovery time 1,5 seconds

(b) Frequency:

- permanent variations ±5 per cent
- transient variations due to step changes in load ±10 per cent
- recovery time 5 seconds

A maximum rate of change of frequency not exceeding ±1,5 Hz per second during cyclic frequency fluctuations.

1.8.3 Unless specified otherwise, the total harmonic distortion (THD) of the voltage waveform at any a.c. switchboard or section-board is not to exceed 8 per cent of the fundamental for all frequencies up to 50 times the supply frequency and no

voltage at a frequency above 25 times supply frequency is to exceed 1,5 per cent of the fundamental of the supply voltage. THD is the ratio of the rms value of the harmonic content to the rms value of the fundamental, expressed in per cent and may be calculated using the expression:

$$THD = \frac{\sqrt{\Sigma_{h=2}^{\infty} V_h^2}}{V_1} \times 100$$

where

V_h = rms amplitude of a harmonic voltage of order *h*

V_1 = rms amplitude of the fundamental voltage.

1.8.4 Where a higher value of THD is specified, all installed equipment and systems are to be designed for the higher specified limit. This relaxation on the limit is to be documented in the harmonic distortion calculation report.

1.8.5 Unless specified otherwise, d.c. electrical equipment is to operate satisfactorily with the following simultaneous variations, from their nominal value, when measured at the consumer input terminals:

(a) When supplied by d.c. generator(s) or a rectified a.c. supply:

Voltage tolerance (continuous) ±10 per cent

Voltage cyclic variation deviation 5 per cent

Voltage ripple 10 per cent

(a.c. rms over steady state d.c. voltage);

(b) When supplied by batteries:

(i) Equipment connected to the batteries during charging:

Voltage tolerance +30 per cent, -25 per cent;

(ii) Equipment not connected to batteries during charging:

Voltage tolerance +20 per cent, -25 per cent

Different voltage variations as determined by the charging/discharging characteristics, including ripple voltage from the charging device, may be considered. When battery chargers/battery combinations are used as d.c. power supply systems adequate measures are to be taken to keep the voltage within the specified limits during charging, boost charging and discharging of the battery.

1.9 Ambient reference and operating conditions

1.9.1 The rating for classification purposes of essential electrical equipment intended for installation in craft to be classed for unrestricted (geographical) service is to be based on an engine room ambient temperature of 45°C, and a sea-water temperature at the inlet of 32°C. The equipment manufacturer is not expected to provide simulated ambient reference conditions at a test bed.

1.9.2 In the case of craft to be classed for restricted service, the rating is to be suitable for the ambient conditions associated with the geographical limits of the restricted service which are part of the class notation.

1.9.3 Main and essential auxiliary machinery and equipment are to operate satisfactorily under the conditions shown in *Pt 9, Ch 1, 4.5 Ambient operating conditions*. Electrical equipment satisfying alternative ambient operating condition requirements for installation on ships contained in an acceptable and relevant National or International Standard may be considered to satisfy this requirement.

Note Details of local environmental conditions are stated in Annex B of IEC 60092-101-2002: *Electrical installations in ships - Part 101: Definitions and general requirements*.

1.9.4 Where electrical equipment is installed within environmentally controlled spaces, the ambient temperature for which the equipment is suitable for operation at its rated capacity may be reduced to a value not less than 35°C provided:

- the equipment is not for use for emergency services and is located outside of machinery space(s);
- temperature control is achieved by at least two cooling units so arranged that, in the event of loss of one cooling unit, for any reason, the remaining unit(s) will be capable of satisfactorily maintaining the design temperature;

- the equipment is able to be initially set to work safely within a 45°C ambient temperature until such a time that the lesser ambient temperature may be achieved; the cooling equipment is to be rated for an ambient temperature of not less than 45°C; and
- alarms are provided, at a continually attended control station, to indicate any malfunction of the cooling units.

See also Pt 16, Ch 1, 1.3 Control, alarm and safety equipment 1.3.3.

1.9.5 Where equipment is to comply with *Pt 16, Ch 2, 1.9 Ambient reference and operating conditions 1.9.4*, it is to be ensured that electrical cables for their entire length are adequately rated for the maximum ambient temperature to which they are exposed along their length.

1.9.6 Equipment used for cooling and maintaining the lesser ambient temperature in accordance with *Pt 16, Ch 2, 1.9 Ambient reference and operating conditions 1.9.4* are considered essential services and are to satisfy the requirements of *Pt 16, Ch 2, 5.2 Essential services*.

1.10 Inclination of craft

1.10.1 Emergency and essential electrical equipment is to operate satisfactorily under the conditions as shown in *Table 1.4.1 Inclinations*.

1.11 Location and construction

1.11.1 All electrical equipment is to be constructed or selected, and installed such that:

(a) live parts cannot be inadvertently touched, unless they are supplied at the safety voltage specified in *Pt 16, Ch 2, 1.12 Earthing of non-current carrying parts 1.12.2.(h)*;
(b) it does not cause injury when handled or touched in the normal manner; and
(c) it is unaffected by any water, steam or oil and oil vapour to which it is likely to be exposed.

Electrical equipment having, as a minimum, the degrees of protection as specified in IEC 60092-201: *Electrical installations in ships – Part 201: System design – General* for the relevant location will satisfy these requirements.

1.11.2 Switchboards, section boards and distribution boards supplying essential and emergency services, as well as cables from the respective generators to and between these boards, are to be arranged to avoid areas of high fire risk and elevated temperatures, for example, in close proximity to incinerators and boilers.

1.11.3 Electrical equipment, as far as is practicable, is to be located:

(a) such that it is accessible for the purpose of maintenance and survey;
(b) clear of flammable material;
(c) in spaces adequately ventilated to remove the waste heat liberated by the equipment under full load conditions, at the ambient conditions specified in *Pt 16, Ch 2, 1.9 Ambient reference and operating conditions*;
(d) where flammable gases cannot accumulate. If this is not practicable, electrical equipment is to be of the appropriate 'safe-type', *see Pt 16, Ch 2, 14 Electrical equipment for use in explosive atmospheres*;
(e) where it is not exposed to the risk of mechanical injury or damage from water, steam or oil.

1.11.4 Equipment design and the choice of materials are to reduce the likelihood of fire, ensuring that:

(a) where the electrical energised part can cause ignition and fire, it is contained within the bounds of the enclosure of the electrotechnical product;
(b) the design, material(s) and construction of the enclosure minimises, as far as is practicable, any internal ignition causing ignition of adjacent materials; and
(c) where surfaces of the electrotechnical products can be exposed to external fire, they do not, as far as practicable, contribute to the fire growth.

Note Compliance with IEC 60695: *Fire hazard testing* (all parts), or an alternative and acceptable Standard, will satisfy this requirement, *see also Pt 16, Ch 2, 1.16 Operation under fire conditions 1.16.5*.

1.11.5 Insulating materials and insulated windings are to be resistant to tracking, moisture, sea air, oil and oil vapour unless special precautions are taken to protect them.

1.11.6 The minimum creepage and clearance distances provided for electrical connections, terminals and similar bare live parts are to be in accordance with a relevant International or National Standard for the equipment or apparatus concerned. In cases where the rated voltage is outside that given in the Standard or where no Standard is available, the minimum creepage and

clearance distances provided are to be in accordance with *Pt 16, Ch 2, 7.5 Creepage and clearance distances*. Details of alternatives proposals including supporting design rationale and demonstration may be submitted for consideration.

1.11.7 Studs, screw-type or spring-type clamp terminations, satisfactory for the normal operating currents and voltages, are to be provided in electrical equipment for the connection of external cable, or bus-bar conductors, as appropriate, *see also Pt 16, Ch 2, 11.15 Electric cable ends*. There is to be adequate space and access for the terminations.

1.11.8 The design of equipment is to enable ease of access to all parts requiring inspection or replacement in service.

1.11.9 Equipment is not to remain alive through the control circuits and/or pilot lamps when switched off by the control switch. This does not apply to synchronising switches and/or plugs.

1.11.10 The operation of all electrical equipment and the lubrication arrangements are to be efficient under such conditions of vibration and shock as arise in normal practice.

1.11.11 All nuts, screws and clamping devices used in connection with current-carrying, supporting and working parts are to be provided with means to ensure that they cannot work loose by vibration and shock as arise in normal practice.

1.11.12 To allow ease of access, connectors are to be spaced far enough apart to permit connection and disconnection. At test points, adequate clearance is to be provided between connection points and controls to provide access for testing.

1.11.13 Conductors and equipment are to be placed at such a distance from the magnetic compasses, or are to be so disposed, that the interfering magnetic field is negligible when circuits are switched on and off.

1.11.14 Where electrical power is used for propulsion, the equipment is to be so arranged that it will operate satisfactorily in the event of partial flooding by bilge water above the tank top up to the bottom floor plate level, under the normal angles of inclination given in *Pt 16, Ch 2, 1.10 Inclination of craft* for essential electrical equipment, *see Pt 15, Ch 2 Ship Piping Systems*.

1.12 Earthing of non-current carrying parts

1.12.1 Except where exempted by *Pt 16, Ch 2, 1.12 Earthing of non-current carrying parts 1.12.2*, all non-current carrying exposed metal parts of electrical equipment and cables are to be earthed for personnel protection against electric shock. Bonding of non-current carrying exposed metal parts is to give a substantially equal potential and a sufficiently low earth fault loop impedance to ensure correct operation of protective devices.

1.12.2 The following parts may be exempted from the requirements of *Pt 16, Ch 2, 1.12 Earthing of non-current carrying parts 1.12.1*:

(a) lamp-caps, where suitably shrouded;
(b) shades, reflectors and guards supported on lampholders or light fittings constructed of, or shrouded in, non-conducting material;
(c) metal parts on, or screws in or through, non-conducting materials, which are separated by such material from current-carrying parts and from earthed non-current carrying parts in such a way that in normal use they cannot become live or come into contact with earthed parts;
(d) apparatus which is constructed in accordance with the principle of double insulation;
(e) bearing housings which are insulated in order to prevent circulation of current in the bearings;
(f) clips for fluorescent lamps;
(g) cable clips and short lengths of pipes for cable protection;
(h) apparatus supplied at a safety voltage not exceeding 50 V d.c. or 50 V a.c., between conductors, or between any conductor and earth in a circuit isolated from the supply. Autotransformers are not to be used for the purpose of achieving the alternating current voltage;
(i) apparatus or parts of apparatus which although not shrouded in insulating material is nevertheless otherwise so guarded that it cannot be touched and cannot come in contact with exposed metal.

1.12.3 Where extraneous-conductive parts (i.e. parts not forming part of the electrical installation and liable to introduce an electric potential) are not bonded by separate earthing conductors, details are to be submitted that demonstrate that a permanent, metal-to-metal connection of negligible impedance, which will not degrade due to corrosion or vibration, will be achieved.

1.12.4 Armouring, braiding and other metal coverings of cables are to be effectively earthed. Where the armouring, braiding and other metal coverings are earthed at one end only, they are to be adequately protected and insulated at the unearthed end with the insulation being suitable for the maximum voltage that may be induced. *See Pt 16, Ch 2, 14.1 General* for earthing of cables in hazardous zones or spaces.

1.12.5 The electrical continuity of all metal coverings of cables throughout the length of the cable, particularly at joints and tappings, is to be ensured.

1.12.6 Metal parts of portable appliances, other than current-carrying parts and parts exempted by *Pt 16, Ch 2, 1.12 Earthing of non-current carrying parts 1.12.2* are to be earthed by means of an earth-continuity conductor in the flexible cable or cord through the associated plug and socket-outlet.

1.12.7 Earthing conductors are to be of copper or other corrosion-resistant material and be securely installed and protected where necessary against damage and also, where necessary, against electrolytic corrosion. Connections are to be so secured that they cannot work loose under vibration.

1.12.8 The nominal cross-section areas of copper earthing conductors are, in general to be equal to the cross-section of the current-carrying conductor up to 16 mm^2. Above this figure they are to be equal to at least half the cross-section of the current-carrying conductor with a minimum of 16 mm^2. Every other earthing conductor is to have a conductance not less than that specified for an equivalent copper earthing conductor.

1.12.9 The connection of the earthing conductor to the hull of the craft is to be made in an accessible position, and is to be secured by a screw or stud of a diameter appropriate for the size of earthing conductor, but not less than 6 mm which is to be used for this purpose only. Bright metallic surfaces at the contact areas are to be ensured immediately before the nut or screw is tightened and, where necessary, the joint is to be protected against electrolytic corrosion. The connection is to remain unpainted.

1.13 Electrical bonding for the control of static electricity

1.13.1 In non-metallic craft, all metallic parts of the craft are to be electrically bonded together, as far as possible, in consideration of galvanic corrosion between dissimilar metals, to ensure an earth return path and to connect the craft to the water when water-borne. This does not apply to isolated components which cannot become live, nor require control of static electricity.

1.13.2 Bonding straps for the control of static electricity are required for piping systems, including pressure refuelling points, which are not electrically continuous throughout their length and for flammable products, which are not permanently connected to the hull of the craft either directly or via their bolted or welded supports and where the resistance between them and the hull exceeds 1MΩ.

1.13.3 Where bonding straps are required for the control of static electricity, they are to be robust, that is, having a cross-sectional area of at least 10 mm^2, and are to comply with *Pt 16, Ch 2, 1.12 Earthing of non-current carrying parts 1.12.7* and *Pt 16, Ch 2, 1.12 Earthing of non-current carrying parts 1.12.9*.

1.14 Labels, signs and notices

1.14.1 Labels, signs and notices required by this Chapter are to be positioned in clearly visible locations which will not be obscured.

1.14.2 Labels, signs and notices are to be easy to read under the expected operating conditions. Character height in accordance with *Table 2.1.1 Character height and viewing distance* will be considered to satisfy this requirement.

1.14.3 Controls, indicators and displays required by this Chapter are to be labelled to indicate their function. Labels are to be positioned in a manner that associates the label with the item being labelled.

1.14.4 Labels, signs and notices are to use short, clear messages. In general, warning signs and notices are to comprise:

- a word signalling the gravity of the risk (e.g. Danger, Warning or Caution);
- a statement of the nature and/or consequence of the hazard; and
- wherever practical, an instruction giving appropriate behaviour to avoid the hazard.

Table 2.1.1 Character height and viewing distance

Work area	Minimum character height (mm)
Less than 500	2,3
500–1000	4,7
1000–2000	9,4

2000–4000	19
4000–8000	38

1.15 Alarms

1.15.1 Where alarms are required by this Chapter they are to be arranged in accordance with *Pt 16, Ch 1, 2.3 Alarm systems*. Sound signal equipment, fire and general alarm bells are not required to be supplemented by visual indications, except in areas having high levels of background noise, such as machinery spaces.

1.15.2 The alarms in this Chapter are additional to those required by *Pt 16, Ch 1 Control Engineering Systems*. They may however form part of the alarm system that is required by *Pt 16, Ch 1 Control Engineering Systems*.

1.15.3 Cables for emergency alarms and their power sources are to be in accordance with *Pt 16, Ch 2, 1.16 Operation under fire conditions*.

1.15.4 Electrical equipment and cables for emergency alarms are to be so arranged that the loss of alarms in any one area due to localised fire, collision, flooding or similar damage is minimised, *see Pt 16, Ch 2, 1.16 Operation under fire conditions*.

1.16 Operation under fire conditions

1.16.1 As a minimum, the following emergency services and their emergency power supplies, are required to be capable of being operated under fire conditions:

- Control and power systems to power-operated fire doors and status indication for all fire doors.
- Control and power systems to power-operated watertight doors and their status indication.
- Emergency lighting.
- Fire and general emergency alarms.
- Fire detection systems.
- Fire-extinguishing systems and fire-extinguishing media release alarms.
- Fire safety stops, *see also Pt 16, Ch 2, 17.6 Fire safety stops*.
- Low location lighting, *see also Pt 16, Ch 2, 18.4 Escape route or low location lighting (LLL) 18.4.3*.
- Public address systems.
- Emergency fire pump.

1.16.2 Where cables for the emergency services listed in *Pt 16, Ch 2, 1.16 Operation under fire conditions 1.16.1* pass through high fire risk areas, or main vertical or horizontal fire zones other than those which they serve, they are to be so arranged that a fire in any of these areas or zones does not affect the operation of the emergency service in any other area or zone. This may be achieved either by:

- cables being of a fire-resistant type complying with *Pt 16, Ch 2, 11.5 Construction 11.5.3*, and at least extending from the main control/monitoring panel to the nearest local distribution panel serving the relevant area or zone; or
- there being at least two-loops/radial distributions run as widely apart as is practicable and so arranged that in the event of damage by fire at least one of the loops/radial distributions remains operational.

1.16.3 Where the cables for the power supplies for the emergency services listed in *Pt 16, Ch 2, 1.16 Operation under fire conditions 1.16.1* pass through high fire risk areas, or main vertical or horizontal fire zones other than those which they serve, they are to be of a fire-resistant type complying with *Pt 16, Ch 2, 11.5 Construction 11.5.3*, extending at least to the local distribution panel serving the relevant area or zone.

1.16.4 Fire-resistant electrical cables for the emergency services listed in *Pt 16, Ch 2, 1.16 Operation under fire conditions 1.16.1*, including their power supplies, are to be run as directly as is practicable, having regard to any special installation requirements, for example those concerning minimum bend radii.

1.16.5 In addition to *Pt 16, Ch 2, 1.11 Location and construction 1.11.4*, materials used for electrical equipment, cables and accessories within passenger accommodation areas are not to be capable of producing excessive quantities of smoke and toxic products.

Note Compliance with IEC 60695: *Fire hazard testing*, or an alternative and acceptable Standard, will satisfy this requirement.

1.17 Lightning protection

1.17.1 In order to minimise the risks of damage to the craft and its electrical installation due to lightning, crafts having non-metallic masts or topmasts are to be fitted with lightning conductors in accordance with the applicable requirements of IEC 60092-401: *Electrical installations in ships – Part 401: Installation and test of completed installation* or an alternative and relevant National Standard.

1.17.2 In addition to the primary protection requirements in *Pt 16, Ch 2, 1.17 Lightning protection 1.17.1*, precautions are to be taken to protect essential electronic equipment that may be susceptible to damage from voltage pulses attributable to the secondary effects of lightning. This may be achieved by suitable design and/or the use of additional protective devices, such as surge arrestors. Resultant induced voltages may be further reduced by the use of earthed metallic screened cables.

1.18 Programmable electronic systems

1.18.1 Where programmable electronic systems are implemented and used to control the electrical installation, or to provide safety functions in accordance with the requirements of this Chapter (e.g. electric propulsion, circuit-breaker settings, switchgear and controlgear controllers, etc.), the arrangements are to satisfy the applicable requirements of *Pt 16, Ch 1, 2.10 Programmable electronic systems – General requirements* to *Pt 16, Ch 1, 2.14 Programmable electronic systems - Additional requirements for integrated systems*.

1.18.2 Where *Pt 16, Ch 2, 1.18 Programmable electronic systems 1.18.1* applies, proposed modifications to software and acceptance testing and trials are to be in accordance with *Pt 16, Ch 1, 1.4 Alterations and additions* and *Pt 16, Ch 2, 7 Switchgear and controlgear assemblies* as applicable.

■ *Section 2*
Main source of electrical power

2.1 General

2.1.1 The main source of electrical power is to comply with the requirements of this Section without recourse to the emergency source of electrical power.

2.2 Number and rating of generators and converting equipment

2.2.1 Under seagoing conditions, the number and rating of service generating sets and converting sets, such as transformers and semi-conductor converters, when any one generating set or converting set is out of action, are:

(a) to be sufficient to ensure the operation of electrical services for essential equipment and habitable conditions;
(b) to have sufficient reserve capacity to permit the starting of the largest motor without causing any motor to stall or any device to fail due to excessive voltage drop on the system;
(c) to be capable of providing the electrical services necessary to start the main propulsion machinery from a `dead craft condition'. The emergency source of electrical power may be used to assist if it can provide power at the same time to those services required to be supplied by *Pt 16, Ch 2, 3 Emergency source of electrical power*, *see also Pt 16, Ch 2, 2.3 Starting arrangements 2.3.2*.

2.2.2 The arrangement of the craft's main source of power is to be such that the operation of electrical services for essential equipment and habitable conditions can be maintained regardless of the speed and direction of the propulsion machinery shafting.

2.2.3 Where the electrical power requirement to maintain the craft in a normal operational and habitable condition is usually supplied by one generating set, arrangements are to be provided to prevent overloading of the running generator, *see Pt 16, Ch 2, 6.9 Load management*. On loss of power there is to be provision for automatic starting and connecting to the main switchboard of the standby set in as short a time as practicable, but in any case within 45 seconds, and automatic sequential restarting of essential services, *see Pt 16, Ch 2, 1.6 Definitions 1.6.1*, in as short a time as practicable.

Note Where the prime mover starting time will result in exceeding this starting and connection time, details are to be submitted for consideration.

2.3 Starting arrangements

2.3.1 The starting arrangements of the generating sets' prime movers are to comply with the requirements of *Pt 10, Ch 1 Reciprocating Internal Combustion Engines* and *Pt 10, Ch 2 Gas Turbines* as applicable.

2.3.2 Where the emergency source of electrical power is required to be used to restore propulsion from a 'dead craft condition', the emergency generator is to be capable of providing initial starting energy for the propulsion machinery within 30 minutes of the 'dead craft condition'. The emergency generator capacity is to be sufficient for restoring propulsion in addition to supplying those services in *Pt 16, Ch 2, 3.2 Emergency source of electrical power in passenger craft and for yachts that are 500 gt or more 3.2.7*, *Pt 16, Ch 2, 3.2 Emergency source of electrical power in passenger craft and for yachts that are 500 gt or more 3.2.7.(b)*, *Pt 16, Ch 2, 3.2 Emergency source of electrical power in passenger craft and for yachts that are 500 gt or more 3.2.7.(c)* for passenger craft and yachts greater than 500gt; or *Pt 16, Ch 2, 3.3 Emergency source of electrical power in craft required to comply with the HSC Code 3.3.7*,*Pt 16, Ch 2, 3.3 Emergency source of electrical power in craft required to comply with the HSC Code 3.3.7.(b)*, *Pt 16, Ch 2, 3.3 Emergency source of electrical power in craft required to comply with the HSC Code 3.3.7.(c)* and *Pt 16, Ch 2, 3.3 Emergency source of electrical power in craft required to comply with the HSC Code 3.3.7.(d)*and*Pt 16, Ch 2, 3.3 Emergency source of electrical power in craft required to comply with the HSC Code 3.3.7.(d)* for craft required to comply with HSC code; or *Pt 16, Ch 2, 3.4 Emergency source of electrical power in cargo craft, patrol and pilot craft, workboats and other similar craft of 500 tons gross tonnage and above; and cargo craft, patrol and pilot craft, workboats and other similar craft less than 500 tons gross tonnage 3.4.3* and*Pt 16, Ch 2, 3.3 Emergency source of electrical power in craft required to comply with the HSC Code 3.3.7.(f)* as applicable. *See Pt 10, Ch 1, 9.1 Dead ship condition starting arrangements 9.1.1* and *Pt 10, Ch 2, 6.1 Initial starting arrangements 6.1.1* for starting arrangements.

2.4 Prime mover governors

2.4.1 The governing accuracy of the generating sets' prime movers is to meet the requirements of *Pt 10, Ch 1 Reciprocating Internal Combustion Engines* and *Pt 10, Ch 2 Gas Turbines*.

2.4.2 The maximum electrical step load switched on or off is not to cause the frequency variation of the electrical supply to exceed the parameters given in *Pt 16, Ch 2, 1.8 Quality of power supplies 1.8.2*, see also *Pt 10, Ch 1 Reciprocating Internal Combustion Engines* and *Pt 10, Ch 2 Gas Turbines*.

2.5 Main propulsion driven generators not forming part of the main source of electrical power

2.5.1 Generators and generator systems, having the craft's propulsion machinery as their prime mover but not forming part of the craft's main source of electrical power may be used whilst the craft is at sea to supply electrical services required for normal operational and habitable conditions provided that the requirements of *Pt 16, Ch 2, 2.5 Main propulsion driven generators not forming part of the main source of electrical power 2.5.2* to *Pt 16, Ch 2, 2.5 Main propulsion driven generators not forming part of the main source of electrical power 2.5.4* are satisfied.

2.5.2 Within the declared operating range of the generators and/or generator system, the specified voltage and frequency variations of the Rules are to be met.

2.5.3 Where there is remote control of the propulsion machinery, arrangements are to ensure that essential machinery power supplies are maintained during manoeuvring conditions in order to prevent a blackout situation.

2.5.4 In addition to the requirements of *Pt 16, Ch 2, 2.2 Number and rating of generators and converting equipment 2.2.3*, arrangements are to be fitted to automatically start one of the generators forming the main source of power should the frequency variations exceed those permitted by the Rules.

■ *Section 3*
Emergency source of electrical power

3.1 General

3.1.1 The requirements of this Section apply to passenger craft, to yachts that are 500 gt or more, to cargo craft, patrol and pilot craft, workboats and other similar craft of 500 tons gross tonnage and above, and to cargo craft, patrol and pilot craft, workboats and other similar craft of less than 500 tons gross tonnage for operation in Service Groups 4 and 5. For other craft, *see Pt 16, Ch 2, 20 Cargo craft, patrol and pilot craft, workboats and other similar craft of less than 500 tons gross tonnage for operation in Service Groups 1 to 3, and yachts less than 500 gt*.

3.1.2 Passenger craft and cargo craft constructed in compliance with the HSC Code are to comply with *Pt 16, Ch 2, 3.3 Emergency source of electrical power in craft required to comply with the HSC Code*. Other specified craft are to comply with *Pt 16, Ch 2, 3.2 Emergency source of electrical power in passenger craft and for yachts that are 500 gt or more* or *Pt 16, Ch 2, 3.4 Emergency source of electrical power in cargo craft, patrol and pilot craft, workboats and other similar craft of 500 tons gross tonnage and above; and cargo craft, patrol and pilot craft, workboats and other similar craft less than 500 tons gross tonnage* as applicable.

3.1.3 The emergency source of power for other craft will be the subject of special consideration, with due regard to the size and the intended service of the craft.

3.1.4 Where the main source of electrical power is located in two or more compartments which are not contiguous, each of which has its own self-contained systems, including power distribution and control systems, completely independent of each other and such that a fire or other casualty in any one of the spaces will not affect the power distribution from the others, or to the services required by *Pt 16, Ch 2, 3.2 Emergency source of electrical power in passenger craft and for yachts that are 500 gt or more*, *Pt 16, Ch 2, 3.3 Emergency source of electrical power in craft required to comply with the HSC Code* or *Pt 16, Ch 2, 3.4 Emergency source of electrical power in cargo craft, patrol and pilot craft, workboats and other similar craft of 500 tons gross tonnage and above; and cargo craft, patrol and pilot craft, workboats and other similar craft less than 500 tons gross tonnage*, the requirements of this Section may be considered satisfied without an additional emergency source of electrical power, provided that:

(a) there is at least one generating set of sufficient capacity to meet the requirements of *Pt 16, Ch 2, 3.2 Emergency source of electrical power in passenger craft and for yachts that are 500 gt or more*,*Pt 16, Ch 2, 3.3 Emergency source of electrical power in craft required to comply with the HSC Code* or *Pt 16, Ch 2, 3.4 Emergency source of electrical power in cargo craft, patrol and pilot craft, workboats and other similar craft of 500 tons gross tonnage and above; and cargo craft, patrol and pilot craft, workboats and other similar craft less than 500 tons gross tonnage* in each of at least two non-contiguous spaces;
(b) the generator sets referred to in *Pt 16, Ch 2, 3.1 General 3.1.4* and their self-contained systems are installed such that a source of electrical power remains available at all times to supply emergency services after damage or flooding in any one compartment.

3.1.5 Non-passenger type craft of 300 tons gross tonnage and above are to comply with *Pt 16, Ch 2, 3.6 Prime mover governor*.

3.2 Emergency source of electrical power in passenger craft and for yachts that are 500 gt or more

3.2.1 A self-contained emergency source of electrical power is to be provided.

3.2.2 The emergency source of electrical power, associated transforming equipment, if any, transitional source of emergency power, emergency switchboard and emergency lighting switchboard are to be located above the waterline in the final condition of damage, be operable in that condition, and be readily accessible from the open deck. They are not to be located forward of the collision bulkhead, if fitted. Consideration may also be given to alternative arrangements, such as *Pt 16, Ch 2, 3.1 General 3.1.4*, which provide an equivalent degree of safety from fire and flooding.

3.2.3 The location of:

- the emergency source of electrical power and associated transforming equipment, if any;
- the transitional source of emergency power;
- the emergency switchboard; and

in relation to:

- the emergency lighting switchboard; in relation to:
- the main source of electrical power, associated transforming equipment, if any; and
- the main switchboard;

is to be such as to ensure that a fire or other casualty in spaces containing:

- the main source of electrical power, associated transforming equipment, if any, and the main switchboard; or
- in any machinery space of Category A;

will not interfere with the supply, control and distribution of emergency electrical power.

3.2.4 The space containing:

- the emergency source of electrical power, associated transforming equipment, if any;

- the transitional source of emergency electrical power; and
- the emergency switchboard;

is not to be contiguous to the boundaries of machinery spaces of Category A or those spaces containing:

- the main source of electrical power, associated transforming equipment, if any; or
- the main switchboard.

3.2.5 Where compliance with *Pt 16, Ch 2, 3.2 Emergency source of electrical power in passenger craft and for yachts that are 500 gt or more 3.2.3* or *Pt 16, Ch 2, 3.2 Emergency source of electrical power in passenger craft and for yachts that are 500 gt or more 3.2.4* is not practicable, details of the proposed arrangements are to be submitted.

3.2.6 Provided that suitable measures are taken for safeguarding independent emergency operation under all circumstances, the emergency generator may be used exceptionally, and for short periods, to supply non-emergency circuits. Failure of the emergency switchboard when being used in other than an emergency is not to put at risk the operation of the craft or yacht.

3.2.7 The electrical power available is to be sufficient to supply all those services that are essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously. The emergency source of electrical power is to be capable, having regard to starting currents and the transitory nature of certain loads, of supplying simultaneously at least the following services for the periods specified hereinafter, if they depend upon an electrical source for their operation:

(a) for a period of 36 hours, emergency lighting:
  (i) at every lifeboat or liferaft preparation station, muster and embarkation station and oversides;
  (ii) in alleyways, stairways and exits, giving access to the muster and embarkation stations;
  (iii) in all service and accommodation alleyways, stairways and exits and personal lift cars;
  (iv) in the machinery spaces, and main generating stations including their control positions;
  (v) in all control stations, machinery control rooms, and at each main and emergency switchboard;
  (vi) at the stowage positions for firemen's outfits and life saving appliances;
  (vii) at the steering gear; and
  (viii) at the fire pump, the sprinkler pump and the emergency bilge pump and at the starting position of their motors.
(b) for a period of 36 hours:
  (i) the navigation lights, and other lights as required by the International Regulations for Preventing Collisions at Sea in force; and
  (ii) the radiocommunications, as required by statutory regulations.
(c) for a period of 36 hours:
  (i) all internal communication equipment required in an emergency;
  (ii) the navigational equipment as required by statutory regulations; where such provision is unreasonable or impracticable this requirement may be waived for craft of less than 5000 tons gross;
  (iii) the fire detection, fire alarm and general alarm system, manual alarms, and the fire door holding and release system; and
  (iv) the intermittent operation of the daylight signalling lamps, the craft's whistle, the manually-operated call points and all internal signals that are required in an emergency;

  unless such services have an independent supply for the period of 36 hours from an accumulator battery, suitably located for use in an emergency;
(d) for a period of 36 hours:
  (i) emergency fire pump;
  (ii) the automatic sprinkler pump, if fitted;
  (iii) the emergency bilge pump and all the equipment essential for the operation of electrically powered remote controlled bilge valves; and
  (iv) essential electrically powered instruments and control for propulsion machinery, if alternate sources of power are not available for such devices.
(e) for a period of 10 min, power drives for directional control devices including those required to direct thrust forward and astern, unless there is a manual alternative complying with *Pt 14, Ch 1, 6.1 Control 6.1.5*;
(f) for a period of half an hour;

(i) any watertight doors required by Chapter 2 to be power operated together with their control, indication and alarm signals;

(ii) the emergency arrangements to bring the lift cars to deck level for the escape of persons. The passenger lift cars may be brought to deck level sequentially in an emergency;

(g) where applicable, the services required by *Pt 16, Ch 2, 2.3 Starting arrangements 2.3.2* and

(h) where applicable, the air compressors for breathing apparatus cylinders referred to in *Pt 16, Ch 2, 17.9 Electrically powered air compressors for breathing air cylinders 17.9.1*.

3.2.8 The emergency source of electrical power may be either a generator or an accumulator battery, which is to comply with the following:

(a) Where the emergency source of electrical power is a generator it is to be:

(i) driven by a suitable prime mover with an independent supply of fuel having a flashpoint (closed cup test) of not less than 43°C;

(ii) started automatically upon failure of the electrical supply from the main source of electrical power and is to be automatically connected to the emergency switchboard; those services referred to in *Pt 16, Ch 2, 3.2 Emergency source of electrical power in passenger craft and for yachts that are 500 gt or more 3.2.7* are then to be transferred automatically to the emergency generating set. The automatic starting system and the characteristics of the prime mover are to be such as to permit the emergency generator to carry its full rated load as quickly as is safe and practicable, subject to a maximum of 45 seconds; and

(iii) provided with a transitional source of emergency electrical power according to *Pt 16, Ch 2, 3.2 Emergency source of electrical power in passenger craft and for yachts that are 500 gt or more 3.2.9*.

(b) Where the emergency source of electrical power is an accumulator battery, it is to be capable of:

(i) carrying the emergency electrical load without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage;

(ii) automatically connecting to the emergency switchboard in the event of failure of the main source of electrical power; and

(iii) immediately supplying at least those services specified in *Pt 16, Ch 2, 3.2 Emergency source of electrical power in passenger craft and for yachts that are 500 gt or more 3.2.9*.

3.2.9 The transitional source of emergency electrical power required by *Pt 16, Ch 2, 3.2 Emergency source of electrical power in passenger craft and for yachts that are 500 gt or more 3.2.8* may consist of an accumulator battery suitably located for use in an emergency which is to operate without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage and be of sufficient capacity and so arranged as to supply automatically in the event of failure of either the main or emergency source of electrical power for half an hour at least the following services, if they depend upon an electrical source for their operation:

(a)

(i) the lighting required by *Pt 16, Ch 2, 3.2 Emergency source of electrical power in passenger craft and for yachts that are 500 gt or more 3.2.7* and *Pt 16, Ch 2, 3.2 Emergency source of electrical power in passenger craft and for yachts that are 500 gt or more 3.2.7.(b)*;

(ii) the services required by *Pt 16, Ch 2, 3.2 Emergency source of electrical power in passenger craft and for yachts that are 500 gt or more 3.2.7*, *Pt 16, Ch 2, 3.2 Emergency source of electrical power in passenger craft and for yachts that are 500 gt or more 3.2.7.(c).(iii)* and *Pt 16, Ch 2, 3.2 Emergency source of electrical power in passenger craft and for yachts that are 500 gt or more 3.2.7.(c).(iv)* unless such services have an independent supply for the period specified from an accumulator battery suitably located for use in an emergency;

(b) with respect to watertight doors:

(i) power to operate the watertight doors but not necessarily simultaneously, unless an independent temporary source of stored energy is provided. The power source should have sufficient capacity to operate each door at least three times i.e. closed-open-closed, against an adverse list of 15°;

(ii) power to the control, indication and alarm circuits for the watertight doors.

3.2.10 The emergency switchboard is to be installed as near as is practicable to the emergency source of electrical power.

3.2.11 Where the emergency source of electrical power is a generator, the emergency switchboard is to be located in the same space unless the operation of the emergency switchboard would thereby be impaired.

3.2.12 No accumulator battery, fitted in accordance with this Section, unless for engine starting, is to be installed in the same space as the emergency switchboard. An indicator is to be mounted in a suitable place on the main switchboard or in the

machinery control room to indicate when the batteries constituting either the emergency source of electrical power or the transitional source of emergency electrical power are being discharged, and provision is to be made to charge them *in situ* from a reliable on board supply.

3.2.13 The emergency switchboard is to be supplied during normal operation from the main switchboard by an interconnector feeder which is to be adequately protected at the main switchboard against overload and short circuit and which is to be disconnected automatically at the emergency switchboard upon failure of the main source of electrical power. Where the system is arranged for feedback operation, the interconnector feeder is also to be protected at the emergency switchboard at least against short circuit.

3.2.14 In order to ensure the ready availability of the emergency source of electrical power to supply circuits required to provide emergency services, arrangements are to be made, where necessary, to automatically non-emergency circuits from the emergency switchboard in the event of overloading to ensure that electrical power is available to the emergency circuits.

3.2.15 Provision is to be made for the periodic testing of the complete emergency system and is to include the testing of automatic starting arrangements.

3.2.16 In addition to the emergency lighting required by *Pt 16, Ch 2, 3.2 Emergency source of electrical power in passenger craft and for yachts that are 500 gt or more 3.2.7* passenger craft with roll on roll off cargo spaces or special category spaces, are to be provided with the following:

(a) in all passenger public spaces and alleyways supplementary electric lighting that can operate for at least three hours when all other sources of electric power have failed and under any condition of heel. The illumination provided is to be such that the approach to the means of escape can be readily seen. The source of power for the supplementary lighting is to consist of accumulator batteries within the lighting units that are continuously charged where practicable, from the emergency switchboard. Consideration may be given to other means of lighting which is at least as effective. The supplementary lighting is to be such that any failure of the lamp will be immediately apparent. Any accumulator battery provided is to be replaced at intervals having regard to the specified service life in the ambient conditions that they are subject to in service.
(b) A portable rechargeable battery operated lamp is to be provided in every crew space alleyway, recreational space and every working space which is normally occupied unless supplementary emergency lighting, as required by (a) is provided.

3.2.17 A lesser period than the 36 hour period specified in *Pt 16, Ch 2, 3.2 Emergency source of electrical power in passenger craft and for yachts that are 500 gt or more 3.2.7*, but not less than 18 hours, may be considered for yachts of 500 gt or more when in accordance with the relevant Statutory Regulations of the National Authority of the country in which the craft is to be registered.

3.3 Emergency source of electrical power in craft required to comply with the HSC Code

3.3.1 The arrangements for the emergency source of electrical power are to satisfy the requirements of this sub- Section and, additionally, *Pt 16, Ch 2, 3.2 Emergency source of electrical power in passenger craft and for yachts that are 500 gt or more 3.2.1*, *Pt 16, Ch 2, 3.2 Emergency source of electrical power in passenger craft and for yachts that are 500 gt or more 3.2.6*, *Pt 16, Ch 2, 3.2 Emergency source of electrical power in passenger craft and for yachts that are 500 gt or more 3.2.8*, *Pt 16, Ch 2, 3.2 Emergency source of electrical power in passenger craft and for yachts that are 500 gt or more 3.2.11* and *Pt 16, Ch 2, 3.2 Emergency source of electrical power in passenger craft and for yachts that are 500 gt or more 3.2.13* to *Pt 16, Ch 2, 3.2 Emergency source of electrical power in passenger craft and for yachts that are 500 gt or more 3.2.15*.

3.3.2 The emergency source of electrical power, associated transforming equipment, if any, transitional source of emergency power, emergency switchboard and emergency lighting switchboard are to be located above the waterline in the final condition of damage, be operable in that condition, and be readily accessible from the open deck. They are not to be located forward of the collision bulkhead, if fitted.

3.3.3 The location of:

- the emergency source of electrical power and associated transforming equipment, if any;
- the transitional source of emergency power;
- the emergency switchboard; and
- the emergency lighting switchboard;

in relation to:

- the main source of electrical power, associated transforming equipment, if any, and;
- the main switchboard;

is to be such as to ensure that a fire or other casualty in spaces containing:

- the main source of electrical power, associated transforming equipment, if any, and the main switchboard;
- or in any machinery space;

will not interfere with the supply, control and distribution of emergency electrical power.

3.3.4 The space containing:

- the emergency source of electrical power, associated transforming equipment, if any;
- the transitional source of emergency electrical power; and
- the emergency switchboard;

is not to be contiguous to the boundaries of machinery spaces and those spaces containing:

- the main source of electrical power, associated transforming equipment, if any; or
- the main switchboard.

3.3.5 Where compliance with *Pt 16, Ch 2, 3.3 Emergency source of electrical power in craft required to comply with the HSC Code 3.3.3* or *Pt 16, Ch 2, 3.3 Emergency source of electrical power in craft required to comply with the HSC Code 3.3.4* is not practicable, details of the proposed arrangements are to be submitted.

3.3.6 For passenger craft with the restrictive notation Passenger (A), the emergency source of power is to be capable of supplying simultaneously the services referred to in *Pt 16, Ch 2, 3.3 Emergency source of electrical power in craft required to comply with the HSC Code 3.3.7*, *Pt 16, Ch 2, 3.3 Emergency source of electrical power in craft required to comply with the HSC Code 3.3.7.(b)* and *Pt 16, Ch 2, 3.3 Emergency source of electrical power in craft required to comply with the HSC Code 3.3.7.(d).(ii)* and *Pt 16, Ch 2, 3.3 Emergency source of electrical power in craft required to comply with the HSC Code 3.3.7.(d).(vi)*, for a period of 5 hours, the services referred to in *Pt 16, Ch 2, 3.3 Emergency source of electrical power in craft required to comply with the HSC Code 3.3.7.(c)* and *Pt 16, Ch 2, 3.3 Emergency source of electrical power in craft required to comply with the HSC Code 3.3.7.(e)* for the periods specified, and, additionally, the 'Not under command' lights for a period of 12 hours.

3.3.7 The electrical power available is to be sufficient to supply all those services that are essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously. The emergency source of electrical power is to be capable, having regard to starting currents and the transitory nature of certain loads, of supplying simultaneously at least the following services for the periods specified hereinafter, if they depend upon an electrical source for their operation:

(a) for a period of 12 hours, emergency lighting:

    (i) at the stowage positions of life-saving appliances and, additionally, for passenger craft at the preparation, launching and deployed positions of survival craft and equipment for embarkation into those craft;
    (ii) at all escape routes, such as alleyways, stairways, exits from accommodation and service spaces, embarkation points, etc.;
    (iii) in the passenger compartments or public spaces, if any;
    (iv) in the machinery spaces, and main emergency generating spaces including their control positions;
    (v) in control stations;
    (vi) at the stowage positions for fireman's outfits; and
    (vii) at the steering gear;

(b) for a period of 12 hours:

    (i) the navigation lights, and other lights required by the *International Regulations for Preventing Collisions at Sea* in force;
    (ii) electrical internal communication equipment for announcements during evacuation;
    (iii) fire detection and general alarm system and manual fire-alarms; and
    (iv) remote control devices of fire-extinguishing systems if electrical;

(c) for a period of four hours of intermittent operation:

    (i) the daylight signalling lamps, if they have no independent supply from their own accumulator battery; and
    (ii) the craft's whistle or siren, if electrically driven;

(d) for a period of 12 hours:

    (i) the navigational equipment as required by statutory Regulations; where such provision is unreasonable or impracticable, this requirement may be waived for craft of less than 5000 gross tonnage;
    (ii) essential electrically powered instruments and controls for propulsion machinery, if alternate sources of power are not available for such devices;
    (iii) emergency fire pump;

(iv) the automatic sprinkler pump and drencher pump, if fitted;

(v) the emergency bilge pump and all the equipment essential for the operation of electrically powered remote controlled bilge valves; and

(vi) the craft radio facilities required to be available in an emergency;

(e) for a period of 10 minutes:

(i) power drives for directional control devices including those required to direct thrust forward and astern, unless there is a manual alternative complying with *Pt 14, Ch 1, 6.1 Control*;

(f) for Passenger (B) craft only, for a period of half an hour:

(i) power operated sliding watertight doors together with their indicators and warning signals.

(g) for any passenger high speed craft with lifts, for a period of half an hour:

(i) the emergency arrangements to bring the lift cars to deck level for the escape of persons. The passenger lift cars may be brought to deck level sequentially in an emergency.

3.3.8 The emergency source of electrical power may be either a generator or an accumulator battery, which is to comply with the following:

(a) Where the emergency source of electrical power is a generator it is to be:

(i) driven by a suitable prime mover with an independent supply of fuel, having a flashpoint (closed cup test) of not less than 43° C;

(ii) started automatically upon failure of the main source of electrical power supply unless a transitional source of emergency electrical power complying with *Pt 16, Ch 2, 3.3 Emergency source of electrical power in craft required to comply with the HSC Code 3.3.9* is provided; where the emergency generator is automatically started, it is to be automatically connected to the emergency switchboard; those services referred to in *Pt 16, Ch 2, 3.3 Emergency source of electrical power in craft required to comply with the HSC Code 3.3.9* are to be connected automatically to the emergency generator; and

(iii) provided with a transitional source of emergency electrical power as specified in *Pt 16, Ch 2, 3.3 Emergency source of electrical power in craft required to comply with the HSC Code 3.3.9*, except on cargo craft where it may be omitted when an emergency generator is provided capable both of supplying the services mentioned in that paragraph and of being automatically started and supplying the required load as quickly as is safe and practicable subject to a maximum of 45 seconds.

(b) Where the emergency source of electrical power is an accumulator battery it is to be capable of:

(i) carrying the emergency electrical load without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage;

(ii) automatically connecting to the emergency switchboard in the event of failure of the main source of electrical power; and

(iii) immediately supplying at least those services specified in *Pt 16, Ch 2, 3.3 Emergency source of electrical power in craft required to comply with the HSC Code 3.3.9*.

3.3.9 The transitional source of emergency electrical power where required by *Pt 16, Ch 2, 3.3 Emergency source of electrical power in craft required to comply with the HSC Code 3.3.8* is to consist of an accumulator battery suitably located for use in an emergency which is to operate without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage and be of sufficient capacity and is to be so arranged as to supply automatically in the event of failure of either the main or the emergency source of electrical power for half an hour at least the following services if they depend upon an electrical source for their operation:

(a) the lighting required by *Pt 16, Ch 2, 3.3 Emergency source of electrical power in craft required to comply with the HSC Code 3.3.7* and *Pt 16, Ch 2, 3.3 Emergency source of electrical power in craft required to comply with the HSC Code 3.3.7.(b)*. For this transitional phase, the required emergency electric lighting, in respect of the machinery space and accommodation and service spaces, may be provided by permanently fixed, individual, automatically charged, relay operated accumulator lamps; and

(b) the services required by *Pt 16, Ch 2, 3.3 Emergency source of electrical power in craft required to comply with the HSC Code 3.3.7.(b)* and *Pt 16, Ch 2, 3.3 Emergency source of electrical power in craft required to comply with the HSC Code 3.3.7.(c)*;

(c) with respect to watertight doors:

(i) power to operate the watertight doors but not necessarily simultaneously, unless an independent temporary source of stored energy is provided. The power source should have sufficient capacity to operate each door at least three times, i.e. closed-open-closed, against an adverse list of 15º, and
(ii) power to the control, indication and alarm circuits for the watertight doors.

Alternatively, the above services may have independent supplies, for the period specified, from accumulator batteries suitably located for use in an emergency

3.3.10 For passenger craft, propulsion and direction system instruments and controls power supplies are to be arranged to provide an uninterruptible supply of emergency power.

3.3.11 No accumulator battery fitted in accordance with this Section, unless for engine starting, is to be installed in the same space as the emergency switchboard. An indicator is to be mounted in a suitable place in the craft's operating compartment to indicate when the batteries constituting either the emergency source of electrical power or the transitional source of electrical power are being discharged, and provision is to be made to charge them *in situ* from a reliable on board supply.

3.3.12 In addition to the emergency lighting required by 3.3.7(a) to (c), passenger craft with roll on - roll off spaces are to be provided with the following:

(a) in all passenger public spaces and alleyways supplementary electric lighting than can operate for at leat three hours when all other sources of electric power have failed and under any condition of heel. The illumination provided is to be such that the approach to the means of escape can be readily seen. The source of power for the supplementary is to consist of accumulator batteries within the lighting units that are continuously charged, where practicable, from the emergency switchboard. Consideration may be given to other means of lighting which is at least as effective. The supplementary lighting is to be such that any failure of the lamp will be immediately apparent. Any accumulator battery provided is to be replaced at intervals having regard to the specified service life in the ambient conditions that they are subject to in service; and
(b) a portable rechargeable battery operated lamp is to be provided in every crew space alleyway, recreational space and every working space which is normally occupied unless supplementary emergency lighting, as required by *Pt 16, Ch 2, 3.3 Emergency source of electrical power in craft required to comply with the HSC Code 3.3.12* is provided.

3.4 Emergency source of electrical power in cargo craft, patrol and pilot craft, workboats and other similar craft of 500 tons gross tonnage and above; and cargo craft, patrol and pilot craft, workboats and other similar craft less than 500 tons gross tonnage

3.4.1 The arrangements for the emergency source of electrical power are to satisfy the requirements of this sub- Section and, additionally, *Pt 16, Ch 2, 3.2 Emergency source of electrical power in passenger craft and for yachts that are 500 gt or more 3.2.1*, *Pt 16, Ch 2, 3.2 Emergency source of electrical power in passenger craft and for yachts that are 500 gt or more 3.2.3*, *Pt 16, Ch 2, 3.2 Emergency source of electrical power in passenger craft and for yachts that are 500 gt or more 3.2.6* and *Pt 16, Ch 2, 3.2 Emergency source of electrical power in passenger craft and for yachts that are 500 gt or more 3.2.10* to *Pt 16, Ch 2, 3.2 Emergency source of electrical power in passenger craft and for yachts that are 500 gt or more 3.2.15*.

3.4.2 The emergency source of electrical power, associated transforming equipment, if any, transitional source of emergency power, emergency switchboard and emergency lighting switchboard are to be located such that the emergency generator and the main generators together meet the requirements of *Pt 16, Ch 2, 3.1 General 3.1.4*.

3.4.3 The electrical power available is to be sufficient to supply all those services that are essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously. The emergency source of electrical power is to be capable, having regard to starting currents and the transitory nature of certain loads, of supplying simultaneously at least the following services for the periods specified hereinafter, if they depend upon an electrical source for their operation:

(a) for a period of three hours, emergency lighting at every survival craft preparation station, muster and embarkation station and over the sides;
(b) for a period of 12 hours, emergency lighting:
   (i) at the stowage positions of life-saving appliances;
   (ii) at all escape routes, such as alleyways, stairways, exits from accommodation and service spaces, embarkation points, etc.;
   (iii) in the public spaces, if any;
   (iv) in the machinery spaces, and main emergency generating spaces including their control positions;
   (v) in control stations;
   (vi) at the stowage positions for fireman's outfits;
   (vii) at the steering gear; and

(viii) at the emergency fire pump, at the sprinkler pump, if any, and at the emergency bilge pump, if any, and at the starting positions of their motors;

(c) for a period of 12 hours:

(i) the navigation lights, and other lights required by the *International Regulations for Preventing Collisions at Sea* in force; and

(ii) the radio communications, as required by statutory regulations;

(d) for a period of 12 hours:

(i) electrical internal communication equipment for announcements during evacuation;

(ii) fire detection and general alarm system and manual fire alarms; and

(iii) remote control devices of fire-extinguishing systems if electrical;

unless such services have an independent supply for a period of 12 hours from an accumulator battery, suitably located for use in an emergency;

(e) for a period of four hours of intermittent operation:

(i) the daylight signalling lamps, if they have no independent supply from their own accumulator battery; and

(ii) the craft's whistle or siren, if electrically driven;

(f) for a period of 12 hours:

(i) the navigational equipment as required by statutory regulations; where such provision is unreasonable or impracticable, this requirement may be waived for craft of less than 5000 tons gross tonnage;

(ii) essential electrically powered instruments and controls for propulsion machinery, if alternate sources of power are not available for such devices;

(iii) emergency fire pump;

(iv) the automatic sprinkler pump and drencher pump, if fitted and;

(v) the emergency bilge pump and all the equipment essential for the operation of electrically powered remote controlled bilge valves.

(g) for a period of 10 min:

(i) power drives for directional control devices including those required to direct thrust forward and astern, unless there is a manual alternative complying with *Pt 14, Ch 1, 6.1 Control 6.1.5*.

(h) for a period of half an hour:

(i) any watertight doors required by Chapter 2 to be power-operated together with their indicators and warning signals; and

(i) where applicable, the services required by *Pt 16, Ch 2, 2.4 Prime mover governors 2.4.2*.

3.4.4 The emergency source of electrical power may be either a generator or an accumulator battery, which is to comply with the following:

(a) Where the emergency source of electrical power is a generator it is to be:

(i) driven by a suitable prime mover with an independent supply of fuel, having a flashpoint (closed cup test) of not less than 43°C;

(ii) started automatically upon failure of the main source of electrical power supply unless a transitional source of emergency electrical power in accordance with *Pt 16, Ch 2, 3.4 Emergency source of electrical power in cargo craft, patrol and pilot craft, workboats and other similar craft of 500 tons gross tonnage and above; and cargo craft, patrol and pilot craft, workboats and other similar craft less than 500 tons gross tonnage 3.4.5* is provided; where the emergency generator is automatically started, it is to be automatically connected to the emergency switchboard; those services referred to in *Pt 16, Ch 2, 3.4 Emergency source of electrical power in cargo craft, patrol and pilot craft, workboats and other similar craft of 500 tons gross tonnage and above; and cargo craft, patrol and pilot craft, workboats and other similar craft less than 500 tons gross tonnage 3.4.5* are to be connected automatically to the emergency generator; and

(iii) provided with a transitional source of emergency electrical power as specified in *Pt 16, Ch 2, 3.4 Emergency source of electrical power in cargo craft, patrol and pilot craft, workboats and other similar craft of 500 tons gross tonnage and above; and cargo craft, patrol and pilot craft, workboats and other similar craft less than 500 tons gross tonnage 3.4.5* unless an emergency generator is provided capable both of supplying the services mentioned in that paragraph and of being automatically started and supplying the required load as quickly as is safe and practicable subject to a maximum of 45 seconds.

(b) Where the emergency source of electrical power is an accumulator battery it is to be capable of:

(i) carrying the emergency electrical load without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage;

(ii) automatically connecting to the emergency switchboard in the event of failure of the main source of electrical power; and

(iii) immediately supplying at least those services specified in *Pt 16, Ch 2, 3.4 Emergency source of electrical power in cargo craft, patrol and pilot craft, workboats and other similar craft of 500 tons gross tonnage and above; and cargo craft, patrol and pilot craft, workboats and other similar craft less than 500 tons gross tonnage 3.4.5*.

3.4.5 The transitional source of emergency electrical power where required by *Pt 16, Ch 2, 3.4 Emergency source of electrical power in cargo craft, patrol and pilot craft, workboats and other similar craft of 500 tons gross tonnage and above; and cargo craft, patrol and pilot craft, workboats and other similar craft less than 500 tons gross tonnage 3.4.4* is to consist of an accumulator battery suitably located for use in an emergency which is to operate without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage and be of sufficient capacity and is to be so arranged as to supply automatically in the event of failure of either the main or the emergency source of electrical power for half an hour at least the following services if they depend upon an electrical source for their operation:

(a) the lighting required by *Pt 16, Ch 2, 3.4 Emergency source of electrical power in cargo craft, patrol and pilot craft, workboats and other similar craft of 500 tons gross tonnage and above; and cargo craft, patrol and pilot craft, workboats and other similar craft less than 500 tons gross tonnage 3.4.3*. For this transitional phase, the required emergency electric lighting, in respect of the machinery space and accommodation and service spaces may be provided by permanently fixed, individual, automatically charged, relay operated accumulator lamps, and

(b) all services required by *Pt 16, Ch 2, 3.4 Emergency source of electrical power in cargo craft, patrol and pilot craft, workboats and other similar craft of 500 tons gross tonnage and above; and cargo craft, patrol and pilot craft, workboats and other similar craft less than 500 tons gross tonnage 3.4.3* and *Pt 16, Ch 2, 3.4 Emergency source of electrical power in cargo craft, patrol and pilot craft, workboats and other similar craft of 500 tons gross tonnage and above; and cargo craft, patrol and pilot craft, workboats and other similar craft less than 500 tons gross tonnage 3.4.3.(e)* unless such services have an independent supply for the period specified from an accumulator battery suitably located for use in an emergency.

(c) with respect to watertight doors:

(i) power to operate the watertight doors but not necessarily simultaneously, unless an independent temporary source of stored energy is provided. The power source should have sufficient capacity to operate each door at least three times i.e. closed-open-closed, against an adverse list of 15°;

(ii) power to the control, indication and alarm circuits for the watertight doors for half an hour.

3.5 Starting arrangements

3.5.1 Where the emergency source of power is a generator, the starting arrangements are to comply with the requirements given in *Pt 10 Prime Movers*.

3.6 Prime mover governor

3.6.1 Where the emergency source of power is a generator, the governor is to comply with *Pt 16, Ch 2, 2.4 Prime mover governors*.

3.7 Radio installation

3.7.1 Every radio installation as required by statutory regulations, is to be provided with reliable, permanently arranged electrical lighting, independent of the main and emergency sources of electrical power, for the adequate illumination of the radio controls for operating the radio installation.

3.7.2 A reserve source or sources of energy is to be provided on every craft, for the purpose of conducting distress and safety radio-communications, in the event of failure of the craft's main and emergency sources of electrical power. The reserve source or sources of energy is to be capable of simultaneously operating the VHF radio installation and, as appropriate for the sea or sea area for which the craft is equipped, either the MF radio installation, the MF/HF radio installation, or the INMARSAT `ship to earth' station and any of the additional loads mentioned in *Pt 16, Ch 2, 3.7 Radio installation 3.7.4*, *Pt 16, Ch 2, 3.7 Radio installation 3.7.5* and *Pt 16, Ch 2, 3.7 Radio installation 3.7.7* for a period of at least one hour. The reserve source or sources of energy need not supply independent HF and MF radio installations at the same time.

3.7.3 The reserve source or sources of energy is to be independent of the propelling power of the craft and the craft's electrical system.

3.7.4 Where, in addition to the VHF radio installation, two or more of the other radio installations, referred to in *Pt 16, Ch 2, 3.7 Radio installation 3.7.2*, can be connected to the reserve source or sources of energy, the reserve source or sources are to be capable of simultaneously supplying, for the period specified by *Pt 16, Ch 2, 3.7 Radio installation 3.7.2*, the VHF radio installation and:

(a) all other radio installations which can be connected to the reserve source or sources of energy at the same time; or
(b) whichever of the other radio installations will consume the most power, if only one of the other radio installations can be connected to the reserve source or sources of energy at the same time as the VHF radio installation.

3.7.5 The reserve source or sources of energy may be used to supply the electrical lighting required by *Pt 16, Ch 2, 3.7 Radio installation 3.7.1*.

3.7.6 Where a reserve source of energy consists of a rechargeable accumulator battery or batteries a means of automatically charging the batteries is to be provided which is to be capable of recharging them to minimum capacity requirements within 10 hours.

3.7.7 If an uninterrupted input of information from the craft's navigational or other equipment to a radio installation as referred to in *Pt 16, Ch 2, 3.7 Radio installation 3.7.2* is needed to ensure its proper performance, means are to be provided to ensure the continuous supply of such information in the event of failure of the craft's main or emergency source of electrical power.

■ *Section 4*
External source of electrical power

4.1 Temporary external supply (shore supply)

4.1.1 Where arrangements are made for the supply of electricity from a source on shore or elsewhere, a connection box is to be installed in a position suitable for the convenient reception of flexible cables from the external source and containing a circuit-breaker or isolating switch and fuses and terminals including one earthed, of ample size and suitable shape to facilitate a satisfactory connection of three-phase external supplies with earthed neutrals.

4.1.2 Suitable cables, permanently fixed, are to be provided, connecting the terminals in the connection box to a linked switch and/or a circuit-breaker at the main switchboard. An indicator is to be provided at the main switchboard in order to show when the cables are energised.

4.1.3 Means are to be provided for checking the phase sequence of the incoming supply.

4.1.4 At the connection box a notice is to be provided giving full information on the system of supply, the normal voltage and frequency of the installation's system and the procedure for carrying out the connection.

4.1.5 Alternative arrangements may be submitted for consideration.

4.2 Permanent external supply

4.2.1 Details are to be submitted.

■ *Section 5*
Supply and distribution

5.1 Systems of supply and distribution

5.1.1 The following systems of generation and distribution are acceptable:

(a) d.c., two-wire;
(b) a.c., single-phase, two-wire;
(c) a.c., three-phase;

three-wire;

four-wire with neutral solidly earthed but without hull return.

5.1.2 System voltages for both alternating current and direct current in general are not to exceed:

(a) 15 000 V for propulsion purposes;

(b) 500 V for power, cooking and heating equipment permanently connected to fixed wiring;

(c) 250 V for lighting, heaters in cabins and public rooms, and other applications not mentioned above;

(d) Voltages exceeding these will be the subject of special consideration.

5.1.3 The arrangement of the main system of supply is to be such that a fire or other casualty in any space containing the main source of electrical power, associated converting equipment, if any, the main switchboard or the main lighting switchboard will not render inoperable any emergency service, other than those located within the space where the fire or casualty has occurred.

5.1.4 The main switchboard is to be so placed relative to the main source of power that, as far as is practicable, the integrity of the main system of supply will be affected only by a fire or other casualty in one space.

5.1.5 The arrangement of the emergency system of supply is to be such that a fire or other casualty in spaces containing the emergency source of electrical power, associated converting equipment, if any, the emergency switchboard and the emergency lighting switchboard, will not cause loss of services required to maintain the propulsion and safety of the craft.

5.1.6 Distribution systems required in an emergency are to be so arranged that a fire in any main vertical zone will not interfere with the emergency distribution in any other such zone.

5.1.7 Feeders from the main and the emergency sources of electrical power are to be separated both vertically and horizontally as widely as is practicable.

5.1.8 For Passenger (A) or Passenger (B) Craft or cargo craft of 500 tons gross tonnage and over, and in any case where the total installed electrical power of the main generating sets is in excess of 3 MW or is supplied at high voltage, arrangements are to be made so that it is possible to split the switchboard, by a multipole linked circuit-breaker, disconnector or switch-disconnector, into at least two independent sections, each supplied by at least one generator.

5.1.9 Where *Pt 16, Ch 2, 5.1 Systems of supply and distribution 5.1.8* is applicable and the essential services which are duplicated are supplied from a section-board, arrangements are to be made so that it is possible to split the section-board into at least two independent sections each supplied by an independent section of the main switchboard either directly or through a transformer.

5.1.10 For Passenger (B) high speed craft, each part of the main busbars with its associated generators is to be arranged in separate compartments.

5.2 Essential services

5.2.1 Essential services that are required to be duplicated are to be served by individual circuits, separated in their switchboard or section board and throughout their length as widely as is practicable without the use of common feeders, protective devices, control circuits or controlgear assemblies, so that any single fault will not cause the loss of both services.

5.2.2 Where *Pt 16, Ch 2, 5.2 Essential services 5.2.1* is applicable the main busbars of the switchboard, or section boards, are to be capable of being split, by removable links or other means, into at least two independent sections, each supplied by at least one generator, either directly or through a converter. The essential services are to be equally divided, as far as is practicable, between the independent sections.

5.2.3 Where *Pt 16, Ch 2, 5.1 Systems of supply and distribution 5.1.8* is applicable provision is to be made to transfer to a temporary circuit those essential services which are not required to be, and have not been, duplicated in the event of loss of their normal section of switchboard or section board.

5.2.4 Where the loss of the electrical supply to a particular essential service which is not duplicated would cause serious risk to the craft, it is to be fed by two independent supplies complying with *Pt 16, Ch 2, 5.2 Essential services 5.2.1*. Such circuits are to be provided with short circuit protection and an overload and phase-failure alarm. Failure of either supply is not to cause risk to the craft during switching to the alternative supply.

5.3 Isolation and switching

5.3.1 The incoming and outgoing circuits from every switchboard or section board are to be provided with a means of isolation and switching to permit each circuit to be switched off:

(a) on load;
(b) for mechanical maintenance;
(c) in an emergency to prevent or remove danger.

Precautions are to be taken to minimise the risk of inadvertent or accidental switching.

5.3.2 Isolation and switching is to be by means of a circuit breaker or switch arranged to open and close simultaneously all insulated poles. Where a switch is used as the means of isolation and switching, it is to be capable of:

(a) switching off the circuit on load;
(b) withstanding, without damage, the overcurrents which may arise during overloads and short circuit.

In addition, these requirements do not preclude the provision of single pole control switches in final sub-circuits, for example light switches. For circuit-breakers, *see Pt 16, Ch 2, 6.5 Circuit-breakers* and *Pt 16, Ch 2, 7.3 Circuit-breakers*.

5.3.3 Provision is to be made, in accordance with one of the following, to prevent any circuit being inadvertently energised:

(a) the circuit breaker or switch can be withdrawn, or locked in the open position;
(b) the operating handle of the circuit breaker or switch can be removed;
(c) the circuit fuses, where fitted, can be readily removed and retained by authorised personnel.

5.3.4 All lighting and power circuits installed in unattended spaces are to be controlled by multipole linked switches situated outside such spaces. Provision is to be made for the complete isolation of these circuits and locking the means of control in the off position.

5.3.5 Where arrangements are in place for automatic changeover between two or more supplies of electrical power in the event of failure of one supply, the arrangements are to be such that a fault in one feeder does not result in the loss of all supplies to the automatic changeover switch.

5.3.6 Where a section board, distribution board or item of equipment can be supplied by more than one circuit, a switching device is to be provided to permit each incoming circuit to be isolated and the supply transferred to the alternative circuit.

5.3.7 The switching device required by *Pt 16, Ch 2, 5.3 Isolation and switching 5.3.6* is to be situated within or adjacent to the section board, distribution board or item of equipment. Where necessary, interlocking arrangements are to be provided to prevent circuits being inadvertently energised.

5.3.8 A notice is to be fixed to any section board, distribution board or item of equipment to which *Pt 16, Ch 2, 5.3 Isolation and switching 5.3.4* applies warning personnel before gaining access to live parts of the need to open the appropriate circuit breakers or switches, unless an interlocking arrangement is provided so that all circuits concerned are isolated before access is gained.

5.4 Insulated distribution systems

5.4.1 A device(s) is to be installed for every insulated distribution system, whether primary or secondary, for power, heating and lighting circuits, to continuously monitor the insulation level to earth and to operate an alarm in the engine control room, or equivalent attended position, in the event of an abnormally low level of insulation resistance.

5.4.2 Where any insulated lower voltage system is supplied through transformers from a high voltage system, adequate precautions are to be taken to prevent the low voltage system being charged by capacitive leakage from the high voltage system.

5.4.3 Where filters are fitted, for example to reduce EMC susceptibility, these are not to cause distribution systems to be unintentionally connected to earth.

5.5 Earthed distribution systems

5.5.1 No fuse, non-linked switch or non-linked circuit-breaker is to be inserted in an earthed conductor. Any switch or circuit-breaker fitted is to operate simultaneously in the earthed conductor and the insulated conductors. These requirements do not preclude the provision (for test purposes) of an isolating link to be used only when the other conductors are isolated.

5.5.2 For high speed craft, earthed electrical distribution systems are not to be used, with the exception of earthed intrinsically safe circuits, in areas where an explosive gas atmosphere may arise from the presence of fuel with a flash point below 43ºC, *see Pt 15, Ch 3, 3.1 Flash point*.

5.5.3 For high voltage systems, where the earthed neutral system of generation and primary distribution is used, earthing is to be through an impedance in order to limit the total earth fault current to a magnitude which does not exceed that of the three phase short circuit current for which the generators are designed.

5.5.4 Generator neutrals may be connected in common, provided that the third harmonic content of the voltage waveform of each generator does not exceed five per cent.

5.5.5 Where a switchboard is split into sections operated independently or where there are separate switchboards, neutral earthing is to be provided for each section or for each switchboard. Means are to be provided to ensure that the earth connection is not removed when generators are isolated.

5.5.6 A means of isolation is to be fitted in the earthing connection of each generator so that generators can be completely isolated for maintenance.

5.5.7 All earthing impedances are to be connected to a common earth connection/bar. The connections to the common earth connection/bar are to be so arranged that any circulating currents in the earth connections do not interfere with radio, radar, communication and control equipment circuits.

5.6 Diversity factor

5.6.1 Circuits supplying two or more final sub-circuits are to be rated in accordance with the total connected load subject, where justified, to the application of a diversity factor. Where spare ways are provided on a section or distribution board, an allowance for future increase of load is to be added to the total connection load before application of any diversity factor.

5.6.2 A diversity factor may be applied to the calculation for size of cable and rating of switchgear and fusegear, taking into account the duty cycle of the connected loads and the frequency and duration of any motor starting loads.

5.6.3 For winches and crane motors the diversity factor is to be calculated and submitted when required.

5.7 Lighting circuits

5.7.1 Lighting circuits are to be supplied by final sub-circuits separate from those for heating and power. This does not preclude the supply from a lighting circuit supplying a single fixed appliance, such as a cabin fan, a dry shaver, a wardrobe or anti-condensation heater, taking a maximum current of 2 A. (This does not apply to cabin and wardrobe heaters).

5.7.2 Lighting for machinery spaces, control stations, normal working spaces, large galleys, corridors, stairways leading to boat decks and in public rooms is to be supplied from at least two final sub-circuits in such a way that failure of any one of the circuits does not leave the space in darkness. One of these circuits may be the emergency circuit, provided it is normally energised.

5.7.3 Lighting for enclosed hazardous spaces is to be supplied from at least two final sub-circuits to permit light from one circuit to be retained while maintenance is carried out on the other.

5.7.4 Emergency lighting is to be fitted in accordance with *Pt 16, Ch 2, 3 Emergency source of electrical power*, *see also Pt 16, Ch 2, 18 Crew and passenger emergency safety systems*.

5.8 Motor circuits

5.8.1 A separate final sub-circuit is to be provided for every motor for essential services, *see Pt 16, Ch 2, 1.6 Definitions 1.6.1*.

5.9 Motor control

5.9.1 Every electric motor is to be provided with efficient means for starting and stopping so placed as to be easily operated by the person controlling the motor. Every motor above 0,5 kW is to be provided with control apparatus as given in *Pt 16, Ch 2, 5.9 Motor control 5.9.2*.

5.9.2 Means to prevent undesired restarting after a stoppage due to low volts or complete loss of volts are to be provided. This does not apply to motors where a dangerous condition might result from the failure to restart automatically, e.g. steering gear motor.

5.9.3 Means for automatic disconnection of the supply in the event of excess current due to mechanical overloading of the motor are to be provided, *see also Pt 16, Ch 2, 6.9 Load management*.

5.9.4 Motor controlgear is to be suitable for the starting current and for the full load rated current of the motor.

5.10 Harmonic distortion measurement

5.10.1 The requirements of *Pt 16, Ch 2, 5.10 Harmonic distortion measurement* apply to electrical distribution systems that include harmonic filters. This requirement applies both to high voltage and low voltage busbars. *See also Pt 16, Ch 2, 6.13 Harmonic filters.* Harmonic filters associated with frequency drives for individual applications (i.e. pump motors) are excluded from the following requirements.

5.10.2 Means are to be provided to continuously monitor the levels of harmonic distortion experienced on the main busbars and to operate an alarm in the engine control room, or equivalent attended position, in the event that the harmonic distortion exceeds the acceptable limits, *see also Pt 6, Ch 1, 4.2 Alarm system for machinery*.

5.10.3 Where the engine room is provided with automation systems to continuously monitor the levels of harmonic distortion experienced on the main busbars, this reading is to be logged electronically; otherwise it is to be measured annually and after any modification to the craft electrical distribution system or associated consumers and recorded in the engine log book for future inspection by the Surveyor.

5.11 Harmonic filtering

5.11.1 The requirements in this Section apply to systems provided with harmonic filters. They apply in particular to, but are not limited to, electrical propulsion systems and are in addition to the requirements for harmonic filters in *Pt 16, Ch 2, 6.13 Harmonic filters*.

5.11.2 Filters used to control harmonic distortion are to keep the distortion within acceptable limits at the main supply. *See also Pt 16, Ch 2, 1.8 Quality of power supplies*.

5.11.3 The service life of the harmonic filter is to be declared, and details are to be included in the harmonic calculation report.

5.11.4 The temperature rating of the harmonic filter is to allow for the increased heating effect of the harmonic distortion.

5.11.5 The construction of cabinets for harmonic filters shall be in accordance with the standards for main switchboards, where applicable. *See also Pt 16, Ch 2, 7 Switchgear and controlgear assemblies*.

5.11.6 The modes of operation of the electrical distribution system for which harmonic distortion levels at the main switchboard busbars are maintained within the acceptable limits during normal operation are to be defined by the system integrator.

5.11.7 Harmonic distortion calculations are to include levels of harmonic distortion expected in normal operation and in the event of a failure of a harmonic filter or the failure of any combination of harmonic filters. *See also Pt 16, Ch 2, 21.2 Trials*.

■ *Section 6*
System design - Protection

6.1 General

6.1.1 Installations are to be protected against overcurrents including short-circuits, and other electrical faults. The tripping/fault clearance times of the protective devices are to provide complete and co-ordinated protection to ensure:

(a) availability of essential and emergency services under fault conditions through discriminative action of the protective devices; as far as practicable the arrangements are also to secure the availability of other services;
(b) elimination of the fault to reduce damage to the system and hazard of fire.

6.1.2 Short-circuit and overload protection are to be provided in each non-earthed line of each system of supply and distribution, unless exempted under the provisions of any paragraph in this Section.

6.1.3 The protection of circuits is to be such that a fault in a circuit does not cause the interruption of supplies used to provide emergency or essential services other than those dependent on the circuit where the fault occurred. For circuits used to provide essential services which need not necessarily be in continuous operation to maintain propulsion and steering but which are necessary for maintaining the vessel's safety, arrangements that ensure that a fault in a circuit does not cause the sustained interruption of supply to healthy circuits may be accepted. Such arrangements are to ensure the supply to healthy circuits is automatically re-established in sufficient time after a fault in a circuit.

6.1.4 Protection systems are to be developed using a systematic design procedure incorporating verification and validation methods to ensure successful implementation of the requirements above. Details of the procedures used are to be submitted when requested. An approved copy of the details required by *Pt 16, Ch 2, 1.2 Documentation required for design review 1.2.5* and *Pt 16, Ch 2, 1.2 Documentation required for design review 1.2.6* is to be retained on board and made available to the Surveyor on request. Access to protection relays setpoints is to be restricted, such that they will generally only be adjusted by authorised personnel to avoid accidental operation. A record is to be kept of the initial setpoints and any subsequent changes made to them. These details are to be made available to the Surveyor on request.

6.1.5 Short-circuit protection is to be provided for each source of power and at each point at which a distribution circuit branches into two or more subsidiary circuits.

6.1.6 Where protection for generator power circuits is provided at the associated switchboard, the cabling between generator and switchboard is to be of a type, and installed in a manner such as to minimise the risk of short-circuit.

6.1.7 Protection for battery circuits is to be provided at a position external and adjacent to the battery compartments. Where arrangements comply with *Pt 16, Ch 2, 12.3 Location 12.3.5*, the protection may be installed at a suitable location in the battery compartment

6.1.8 Protection may be omitted from the following:

(a) Engine starting battery circuits.
(b) Circuits for which it can be shown that the risk resulting from spurious operation of the protective device may be greater than that resulting from a fault.

6.1.9 Short-circuit protection may be omitted from cabling or wiring to items of equipment internally protected against short-circuit or where it can be shown that they are unlikely to fail to a short-circuit condition or it is impractical for operational reasons (e.g. within battery compartments), and where the cabling or wiring is installed in a manner such as to minimise the risk of short-circuit.

6.1.10 Overload protection may be omitted from the following:

(a) one line of circuits of the insulated type;
(b) circuits supplying equipment incapable of being overloaded, or overloading the associated supply cable, under normal conditions, and unlikely to fail to an overload condition.

6.2 Protection against short-circuit

6.2.1 Protection against short-circuit currents is to be provided by circuit-breakers or fuses.

6.2.2 The rated short-circuit making and breaking capacity of every protective device is to be adequate for the prospective fault level at its point of installation; the requirements for circuit breakers and fuses are detailed in *Pt 16, Ch 2, 6.4 Protection against earth faults* and *Pt 16, Ch 2, 6.5 Circuit-breakers* respectively.

6.2.3 The prospective fault current is to be calculated for the following set of conditions:

(a) all generators, motors and, where applicable, all transformers, connected as far as permitted by any interlocking arrangements;
(b) a fault of negligible impedance close up to the load side of the protective device.

6.2.4 In the absence of precise data, the prospective fault current may be taken to be:

(a) for alternating current systems at the main switchboard: 10 x f.l.c. (rated full load current) for each generator that may be connected, or, if the subtransient direct axis reactance, X''_d, of each generator is known, $\frac{\text{f.l.c}}{X''_d\text{(p.u.)}}$ for each generator and 3 x f.l.c. for motors simultaneously in service;

The value derived from the above is an approximation to the r.m.s. symmetrical fault current; the peak asymmetrical fault current may be estimated to be 2,5 times this figure (corresponding to a fault power factor of approximately 0,1).

(b) battery-fed direct current systems at the battery terminals:
    (i) 15 times ampere hour rating of the battery for vented lead-acid cells, or of alkaline type intended for discharge at low rates corresponding to a battery duration exceeding three hours, or
    (ii) 30 times ampere hour rating of the battery for sealed lead-acid cells having a capacity of 100 ampere hours or more, or of alkaline type intended for discharge at high rates corresponding to a battery duration not exceeding three hours and,
    (iii) 6 x f.l.c. for motors simultaneously in service, if applicable.

6.3 Protection against overload

6.3.1 Fuses, circuit breakers and other protective devices provided for overload protection are to have fusing/tripping characteristics ensuring the protection of cabling and electrical machinery against overheating resulting from mechanical or electrical overload.

6.3.2 Fuses of a type intended for short-circuit protection only (e.g. high-voltage fuses or fuses complying with IEC 60269-1: Low-voltage fuses – Part 1: General requirements, of type ‘a’) are not to be used for overload protection.

6.4 Protection against earth faults

6.4.1 Every distribution system that has an intentional connection to earth, by way of an impedance, is to be provided with a means to continuously monitor and indicate the current flowing in the earth connection.

6.4.2 If the current in the earth connection exceeds 5 A there is to be an alarm and the fault current is to be automatically interrupted or limited to a safe value.

6.4.3 The rated short circuit capacity of any device used for interrupting earth fault currents is to be not less than the prospective earth fault current at its point of installation.

6.4.4 Insulated neutral systems with harmonic distortion of the voltage waveform, which may result in earth fault currents exceeding the level given in *Pt 16, Ch 2, 6.4 Protection against earth faults 6.4.2* because of capacitive effects, are to be provided with arrangements to isolate the faulty circuit(s).

6.5 Circuit-breakers

6.5.1 Circuit-breakers for alternating current systems are to satisfy the following conditions:

(a) the r.m.s. symmetrical breaking current for which the device is rated is to be not less than the r.m.s. value of the a.c. component of the prospective fault current, at the instant of contact separation (i.e. first half cycle, or time of interruption where an intentional time delay is provided to ensure suitability);

(b) the peak asymmetrical making current for which the device is rated is not to be less than the peak value of the prospective fault current at the first half cycle, allowing for maximum asymmetry;

(c) the power factor at which the device short circuit ratings are assigned is to be no greater than that of the prospective fault current; alternatively for high voltage, the rated percentage d.c. component of the short-circuit breaking current of the device is to be not less than that of the prospective fault current.

6.5.2 Circuit-breakers for d.c. systems are to have a breaking current not less than the initial prospective fault current. The time constant of the fault current is not to be greater than that for which the circuit-breaker was tested.

6.5.3 The fault ratings considered in *Pt 16, Ch 2, 6.5 Circuit-breakers 6.5.1* and *Pt 16, Ch 2, 6.5 Circuit-breakers 6.5.2*, are to be assigned on the basis that the device is suitable for further use after fault clearance.

6.5.4 Circuit- breaker selection is, and ratings are, to be in accordance with the relevant requirements of IEC 60092- 202: *Electrical installations in ships – Part 202: System design – Protection*. Alternative methods acceptable to LR of selecting suitable circuit-breakers may be considered.

6.6 Fuses

6.6.1 Fuses for a.c. systems are to have a breaking current rating not less than the initial r.m.s. value of the a.c. component of the prospective fault current.

6.6.2 Fuses for d.c. systems are to have a d.c. breaking current rating not less than the initial value of the prospective fault current.

6.7 Circuit-breakers requiring back-up by fuse or other device

6.7.1 The use of a circuit-breaker having a short-circuit current capacity less than the prospective short-circuit current at the point of installation is permitted, provided that it is preceded by a device having at least the necessary short-circuit capacity. The generator circuit breakers are not to be used for this purpose.

6.7.2 The same device may back-up more than one circuit-breaker provided that no essential or emergency service is supplied from there, or that any such service is duplicated by arrangements unaffected by tripping of the device.

6.7.3 The combination of back-up device and circuit-breaker is to have a short circuit performance at least equal to that of a single circuit-breaker satisfying the requirements of *Pt 16, Ch 2, 6.5 Circuit-breakers*.

6.7.4 Evidence of testing of the combination is to be submitted for consideration; alternatively, consideration may be given to arrangements where it can be shown that:

(a) the takeover current, above which the back-up device would clear a fault, is not greater than the rated short-circuit breaking capacity of the circuit-breaker and;
(b) the characteristics of the back-up device, and the prospective fault level, are such that the peak fault current rating of the circuit-breaker cannot be exceeded and;
(c) the Joule integral of the let-through current of the back-up device does not exceed that corresponding to the rated breaking current and opening time of the circuit-breaker.

6.8 Protection of generators

6.8.1 The protective gear required by *Pt 16, Ch 2, 6.8 Protection of generators 6.8.2* and *Pt 16, Ch 2, 6.8 Protection of generators 6.8.3* is to be provided as a minimum.

6.8.2 Generators not arranged to run in parallel are to be provided with a circuit-breaker arranged to open simultaneously, in the event of short-circuit, overload or under-voltage, all insulated poles. In the case of generators rated at less than 50 kW, a multiple linked switch with a fuse, complying with *Pt 16, Ch 2, 5.3 Isolation and switching 5.3.2*, in each insulated pole will be acceptable.

6.8.3 Generators arranged to operate in parallel are to be provided with a circuit-breaker arranged to open all insulated poles simultaneously in the event of a short-circuit, an overload or an under-voltage. This circuit-breaker is to be provided with reverse power protection with time delay, selected or set within the limits of two per cent to 15 per cent of full load to a value fixed in accordance with the characteristics of the prime mover. A fall of 50 per cent in the applied voltage is not to render the reverse power mechanism inoperative, although it may alter the amount of reverse power required to open the breakers.

6.8.4 The generator circuit-breaker short-circuit and overload tripping arrangements, or fuse characteristics, are to be such that the machine's thermal withstand capability is not exceeded.

6.8.5 All high-voltage generators and low-voltage generators having a capacity of 1500 kVA or above are to be equipped with a protective device which, in the event of a short-circuit in the generator or in the cables between the generator and its circuit-breaker, will instantaneously open the circuit-breaker and de-excite the generator.

6.8.6 The voltage and time delay settings of the under-voltage release mechanism(s) required by:

- *Pt 16, Ch 2, 6.8 Protection of generators 6.8.2* and
- *Pt 16, Ch 2, 6.1 General 6.1.1*

are to be chosen to maintain the discriminative action detailed in *Pt 16, Ch 2, 6.1 General 6.1.1*

6.9 Load management

6.9.1 Arrangements are to be made to disconnect automatically, after an appropriate time delay, circuits of the categories noted below, when the generator(s) is/are overloaded; sufficient to ensure the connected generating set(s) is/are not overloaded:

(a) non-essential circuits;
(b) circuits feeding services for habitability, *see Pt 16, Ch 2, 1.6 Definitions 1.6.2*;
(c) in cargo craft, circuits for cargo refrigeration.

> Note For emergency generators *see Pt 16, Ch 2, 3.2 Emergency source of electrical power in passenger craft and for yachts that are 500 gt or more 3.2.12*, with *Pt 16, Ch 2, 3.3 Emergency source of electrical power in craft required to comply with the HSC Code 3.3.1* or *Pt 16, Ch 2, 3.4 Emergency source of electrical power in cargo craft, patrol and pilot craft, workboats and other similar craft of 500 tons gross tonnage and above; and cargo craft, patrol and pilot craft, workboats and other similar craft less than 500 tons gross tonnage 3.4.1* where applicable.

6.9.2 If required, this load switching may be carried out in one or more stages, in which case the non-essential circuits are to be included in the first group to be disconnected.

6.9.3 An alarm is to be provided to indicate when such switching has taken place.

6.9.4 Consideration is to be given to providing means to inhibit automatically the starting of large motors, or the connection of other large loads, until sufficient generating capacity is available to supply them.

6.9.5 When the electric generating plant is fitted with automatic or remote controls so that under normal operating conditions it does not require any manual intervention by the operators, it is to be provided with audible and visual alarms for:

(a) Busbar voltage; high or low.
(b) Busbar frequency; low.
(c) Operating of load shedding.
(d) Generator cooling air temperature high; closed air circuit machines only.

6.10 Feeder circuits

6.10.1 Isolation and protection of each feeder circuit is to be ensured by a multiple circuit-breaker or linked switch with a fuse in each insulated conductor. Protection is to be in accordance with *Pt 16, Ch 2, 6.2 Protection against short-circuit* and *Pt 16, Ch 2, 6.3 Protection against overload*. The protective devices are to allow excess current to pass during the normal accelerating period of motors.

6.11 Motor circuits

6.11.1 Motors of rating exceeding 0,5 kW and all motors for essential services are to be protected individually against overload and short circuit. For motors which for essential services are duplicated, the overload protection may be replaced by an overload alarm; arrangements for steering unit motors are to comply with *Pt 16, Ch 2, 15.1 Steering systems*.

6.11.2 Protection for both the motor and its supply cable may be provided by the same device, provided that due account is taken of any differences between ratings of cable and motor.

6.11.3 Where operation of an item of equipment is dependent upon a number of motors, consideration may be given to the provision of a common means of short-circuit protection.

6.11.4 For motors for intermittent service, the characteristics of the arrangements for overload protection are to be chosen in relation to the load factor(s) of the motor(s).

6.11.5 Where fuses are used to protect polyphase motor circuits, means are to be provided to protect the motor from unacceptable overcurrent in the case of single phasing.

6.12 Protection of transformers

6.12.1 Short circuit protection for transformers is to be provided by circuit breakers or fuses in the primary circuit and in addition, overload protection is to be provided either in the primary or secondary circuit.

6.12.2 Arrangements are to be made to prevent the primary windings of transformers being inadvertently energised from their secondary side when disconnected from their source of supply.

6.13 Harmonic filters

6.13.1 Harmonic filters' final sub-circuits are to be protected individually and individually on each phase against overload and short-circuit. The activation of the protection arrangement in a single phase shall result in automatic disconnection of the complete filter.

6.13.2 A current imbalance detection system protection is to be installed; it is to be independent from the protection specified in *Pt 16, Ch 2, 6.13 Harmonic filters 6.13.1*.

6.13.3 An alarm is to be initiated in the event of protective device operation or current unbalance that could lead to failure of a harmonic filter.

6.13.4 Current imbalance circuits are to be 'fail safe'. The characteristics of the 'fail safe' operation are to be evaluated on the basis, not only of the system and its associated machinery, but also the complete installation, as well as the ship.

6.13.5 The reconnection of harmonic filters is to require manual intervention.

6.13.6 Individual harmonic filter capacitors are to be provided with a pressure relief valve or overpressure disconnector to protect against damage from rupture where pressure build-up within hermetically sealed capacitors may occur.

■ Section 7
Switchgear and controlgear assemblies

7.1 General requirements

7.1.1 Switchgear and controlgear assemblies and their components are to comply with the following standards, as appropriate for the nominal voltage, and amended where necessary for ambient temperature and other environmental conditions:

(a) IEC 61439: *Low-voltage switchgear and controlgear assemblies*(relevant parts);
(b) IEC 62271-200:*High-voltage switchgear and controlgear —Part 200: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV*;
(c) IEC 62271-201: *High voltage switchgear and controlgear — Part 201: AC insulation-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV*;
(d) IEC 60092-503: *Electrical installations in ships – Part 503: Special features – AC supply systems with voltages in the range of above 1 kV up to and including 15 kV*;
(e) IEC 60255: *Measuring relays and protection equipment*; or
(f) an acceptable and relevant National Standard.

In addition, the requirements of *Pt 16, Ch 2, 7.2 Busbars* to *Pt 16, Ch 2, 7.19 Disconnectors and switch-disconnectors* are to be complied with.

7.2 Busbars

7.2.1 Busbars and their connections are to be of copper or aluminium, all connections being so made as to inhibit corrosion/ oxidation between current-carrying mating faces, which may result in poor electrical contact giving rise to over-heating. Busbars and their supports are to be designed to withstand the mechanical stresses which may arise during short-circuits. A test report or calculation to verify the short-circuit withstand strength of the busbar system is to be submitted for consideration when required.

7.2.2 The maximum permissible temperature rise for bare conductors is 45°C. A test report or calculation to verify the rated current assigned to the busbar system is to be submitted for consideration when required.

7.3 Circuit-breakers

7.3.1 Circuit-breakers are to comply with one of the following standards amended where necessary for ambient temperature:

(a) IEC 60947-2: *Low-voltage switchgear and controlgear – Part 2: Circuit-breakers*; or
(b) IEC 62271-100: *High-voltage switchgear and controlgear – Part 100: Alternating current circuit-breakers*; or
(c) an acceptable and relevant National Standard.

Type test reports to verify the characteristics of a circuit-breaker are to be submitted for consideration when required.

7.3.2 Circuit-breakers are to be capable of isolation.

7.3.3 Circuit-breakers are to be of the trip free type and, where applicable, be fitted with anti-pumping control.

7.3.4 High-voltage circuit-breakers are to be of the withdrawable type or with equivalent means or arrangements permitting safe maintenance whilst the busbars are live.

7.3.5 Where the means of setting adjustable protection characteristics are not durably marked and locked in position and cannot be visually inspected (e.g. electronic storage), the settings of characteristics are to be recorded and a copy of the records included in the details retained on board, *see Pt 16, Ch 2, 6.1 General 6.1.4*.

7.3.6 Air circuit-breakers for essential or emergency services and rated at 800A and above are to have a cumulative count kept of the switching operations of the electrical contacts. This count, along with the manufacturer's details for the circuit-breaker, including the maximum number of switching operations for the electrical contacts, is to be retained on board. These details are to be made available to the Surveyor on request.

7.4 Contactors

7.4.1 High-voltage contactors are to comply with one of the following standards amended where necessary for ambient temperature.

(a) IEC 62271-106:*High-voltage switchgear and controlgear – Part 106: Alternating current contactors, contactor-based controllers and motor-starters; or*.

(b) an acceptable and relevant National Standard.

Type test reports to verify the characteristics of a contactor are to be submitted for consideration when required.

7.4.2 High-voltage contactors are to be of the withdrawable type or with equivalent means or arrangements permitting safe maintenance whilst the busbars are live.

7.5 Creepage and clearance distances

7.5.1 The shortest distances between conductive parts and between conductive parts and earth, in air or along the surface of an insulating material, are to be suitable for the rated voltage having regard to:

- the nature of the insulating material;
- the transient over voltages developed by switching and fault conditions; and
- the environment into which the assembly will be installed.

Each assembly type is to be subjected to an impulse voltage test in accordance with its constructional Standard or, alternatively, the minimum distances for bare conductive parts in switchgear and controlgear assemblies given in *Table 2.7.1 Minimum clearance distances* are to be used.

Table 2.7.1 Minimum clearance distances

Nominal voltage (V)	Minimum clearance distance (mm)		
	Verified assemblies, *see* Note 2		Non verified assemblies
	Main switchboards	Other switchgear and control gear	Main switchboards and other switch and controlgear
≤ 250 (*see* Note 1)	8	8	15
≤690 (*see* Note 1)	8	8	20
≤1000 (*see* Note 1)	8	8	25
<3,300	32	26	55
<6600	60	50	90
<11,000	100	80	120
≤15,000	*See* Note 3	*See* Note 3	160

Note 1 For assemblies installed in spaces where the pollution degree is > 3, *see Pt 16, Ch 2, 7.5 Creepage and clearance distances 7.5.2*.

Note 2 For the verification requirements for a verified assembly refer to IEC 61439-2.

Note 3 Clearance distances with reference to the applicable relevant National or International Standards, are to be submitted for approval, *see Pt 16, Ch 2, 1.3 Documentation required for supporting evidence 1.3.4*.

7.5.2 For assemblies with a rated voltage of up to and including 1kV, the requirement of *Pt 16, Ch 2, 7.5 Creepage and clearance distances 7.5.1* may be met by complying with IEC 60092-302 *Electrical installations in ships – Part 302: Low-voltage switchgear and controlgear assemblies.*

- *Table 2.7.1 Minimum clearance distances* and *Table 2.7.2 Minimum creepage distances* indicate the minimum clearance and creepage distances normally allowed.
- For assemblies installed in spaces where the environmental conditions are in excess of pollution degree 3 (that is conductive pollution occurs or dry, non-conductive pollution occurs which is expected to be conductive due to condensation) as defined in IEC 61439-1, *Low-voltage switchgear and controlgear assemblies – Part 1: General requirements*; the clearance distances for non-verified assemblies are to be used.
- A minimum creepage distance of 16 mm is permitted for assemblies verified in accordance with the requirements of IEC 61439-2, *Low-voltage switchgear and controlgear assemblies – Part 2: Power switchgear and controlgear assemblies.*

- An alternative relevant National or International Standard may be used when an acceptable justification is submitted as part of the documentation required by *Pt 16, Ch 2, 1.3 Documentation required for supporting evidence 1.3.4*.

7.5.3 For assemblies with a rated voltage above 1kV, the requirement of *Pt 16, Ch 2, 7.5 Creepage and clearance distances 7.5.1* may be met by complying with IEC 60092-503 *Electrical installations in ships – Part 503: Special features – AC supply systems with voltages in the range of above 1 kV up to and including 15 kV*.

- *Table 2.7.1 Minimum clearance distances* and *Table 2.7.2 Minimum creepage distances* indicate the minimum clearance and creepage distances normally allowed.
- For main switchboards rated at above 1kV, a minimum clearance distance of 25 mm is required for busbars and other bare conductors.

An alternative relevant National or International Standard may be used when an acceptable justification is submitted as part of the documentation required by *Pt 16, Ch 2, 1.3 Documentation required for supporting evidence 1.3.4*.

Table 2.7.2 Minimum creepage distances

Nominal voltage (V)	Minimum creepage distance (mm)	
	Main switchboards	Other switchgear and controlgear
≤ 250 (*see* Note 1)	20	20
≤690 (*see* Note 1)	25	25
≤1000 (*see* Note 1)	35	35
<3,300	48	*See* Note 2
<6,600	90	70
<11, 000	150	120
≤15, 000	*See* Note 2	*See* Note 2

Note 1 For verified assemblies a minimum creepage distance of 16 mm is permitted for LV switchboards, *see Pt 16, Ch 2, 7.5 Creepage and clearance distances 7.5.2*.

Note 2 Creepage distances, with reference to the applicable relevant National or International Standards, are to be submitted for approval, *see Pt 16, Ch 2, 1.3 Documentation required for supporting evidence 1.3.4*.

7.5.4 Suitable shrouding or barriers are to be provided in way of connections to equipment, where necessary, to maintain the minimum distances in *Table 2.7.1 Minimum clearance distances*.

7.6 Degree of protection

7.6.1 Low voltage assemblies where the rated voltage between conductors or to earth exceeds 55 V a.c. or 250 V d.c. are to be of the deadfront or enclosed type. High-voltage assemblies are to be of the enclosed type.

7.6.2 Where switchboards or section boards are required to comply with *Pt 16, Ch 2, 5.2 Essential services 5.2.2*, barriers are to be installed to provide protection for the independent sections against contamination due to the products of arcing, which may result in a fault.

7.6.3 Segregation between low-voltage and high-voltage circuits and equipment installed within common assemblies is to be in accordance with IEC 62271-1: *High-voltage switchgear and controlgear – Part 1: Common specifications*.

7.7 Distribution boards

7.7.1 Distribution boards are to be suitably enclosed unless they are installed in a cupboard or compartment to which only authorised persons have access in which case the cupboard may serve as an enclosure. *See Pt 16, Ch 2, 7.16 Position of switchboards 7.16.4*.

7.8 Earthing of high-voltage switchboards

7.8.1 High-voltage switchboards are to be provided with suitable means to earth isolated circuits so that they are discharged and so maintained that they are safe to touch.

7.8.2 Protective shutters associated with withdrawable parts are to be clearly marked to indicate the incoming and outgoing circuits and bus tie connections. The colour coding shall be as follows:

- Incoming (busbar side) – red;
- Outgoing (Circuit side) – yellow; and
- Bus ties – red

7.9 Fuses

7.9.1 Fuses are to comply with one of the following standards amended where necessary for ambient temperature.

(a) IEC 60269: *Low-voltage fuses*(all parts);
(b) IEC 60282-1: *High-voltage fuses – Part 1: Current-limiting fuses*;
(c) acceptable and relevant National Standard for enclosed current-limiting fuses.

Type test reports to verify the characteristics of a fuse are to be submitted for consideration when required.

7.10 Handrail or handles

7.10.1 All main and emergency switchboards are to be provided with an insulated handrail or insulated handles suitably fitted on the front of the switchboard. Where access to the rear is required, a horizontal insulated handrail is to be suitably fitted on the rear of the switchboard.

7.11 Instruments for alternating current generators

7.11.1 For alternating current generators not operated in parallel, each generator is provided with at least one voltmeter, one frequency meter, and one ammeter with an ammeter switch to enable the current in each phase to be read, or an ammeter in each phase. Generators above 50 kVA are also to be provided with a wattmeter.

7.11.2 For alternating current generators operated in parallel, each generator is to be provided with a wattmeter, and one ammeter with an ammeter switch to enable the current in each phase to be read, or an ammeter in each phase.

7.11.3 For parallelling purposes, two voltmeters, two frequency meters and two synchronising devices, of which one at least is to be a synchroscope or a set of lamps are to be provided. One voltmeter and one frequency meter are to be connected to the busbars, the other voltmeter and frequency meter are to be switched to enable the voltage and frequency of any generator to be measured. Where the electrical power requirement to maintain the ship in a normal operational and habitable condition is usually supplied by two or more generators operating in parallel, the two synchronising devices are to be independent of each other, *see also Pt 16, Ch 2, 2.2 Number and rating of generators and converting equipment 2.2.1*.

7.11.4 The indicators and displays required by *Pt 16, Ch 2, 7.11 Instruments for alternating current generators 7.11.1* are to be located and arranged such that they may be viewed at a single operating position. Where manual paralleling is provided, generators are to have controls to adjust their voltage and frequency located at the single operating position. Access to voltage adjustment is to be restricted, such that it can only be used by authorised personnel to avoid accidental operation.

7.11.5 Where the indications of voltage, frequency, current and power are displayed digitally, the indications are to be separately displayed.

7.12 Instrument scales

7.12.1 The upper limit of the scale of every voltmeter is to be approximately 120 per cent of the nominal voltage of the circuit, and the nominal voltage is to be clearly indicated.

7.12.2 The upper limit of the scale of every ammeter is to be approximately 130 per cent of the normal rating of the circuit in which it is installed. Normal full load is to be clearly indicated.

7.12.3 Kilowatt meters for use with alternating current generators which may be operated in parallel are to be capable of indicating 15 per cent reverse power.

7.12.4 Where the indications provided by the instrumentation required by *Pt 16, Ch 2, 7.11 Instruments for alternating current generators* are displayed digitally, nominal voltage, over voltage, over current and reverse power indications are to be indicated by an appropriate means. The information provided is to be clearly visible and immediately available.

7.12.5 In general, indications provided by instrumentation which are displayed digitally are not to change more frequently than twice per second.

7.13 Labels

7.13.1 The identification of individual circuits and their devices is to be made on labels of durable material. The ratings of fuses and settings of protective devices are also to be indicated. Section and distribution boards are to be marked with the rated voltage.

7.14 Protection

7.14.1 For details of the electrical protection required of switchgear and controlgear, *see Pt 16, Ch 2, 6 System design - Protection*.

7.15 Wiring

7.15.1 Insulated wiring connecting components are to be stranded, flame retardant and manufactured in accordance with a relevant and acceptable National Standard.

7.16 Position of switchboards

7.16.1 An unobstructed space not less than 1 m wide is to be provided in front of switchboards and section boards. When switchboards and section boards contain withdrawable equipment the unobstructed space is to be not less than 0,4 m wide with this equipment in its fully withdrawn position.

7.16.2 Where necessary, the space at the rear of switchboards and section boards is to be ample to permit maintenance and in general not less than 0,6 m except that this may be reduced to 0,5 m in way of stiffeners or frames.

7.16.3 The spaces defined in *Pt 16, Ch 2, 7.16 Position of switchboards 7.16.1* and *Pt 16, Ch 2, 7.16 Position of switchboards 7.16.2* are to have non-slip surfaces. Where access to live parts within switchboards and section boards is normally possible the surface is, in addition, to be electrically insulated.

7.16.4 So far as is practicable, pipes are not to be installed directly above or in front of or behind switchboards, section boards and distribution boards. If such placing is unavoidable, suitable protection is to be provided in these positions, *see Pt 15, Ch 2, 2.5 Testing after installation*.

7.16.5 For switchgear and controlgear assemblies, for rated voltages above 1 kV, arrangements are to be made to protect personnel in the event of gases or vapours escaping under pressure as the result of arcing due to an internal fault. Where personnel may be in the vicinity of the equipment when it is energised, this may be achieved by an assembly that has been tested in accordance with Annex A of IEC 62271- 200 - 2011: *High-voltage switchgear and controlgear – Part 200: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV* and qualified for classification **IAC** (internal arc classification).

7.17 Switchboard auxiliary power supplies

7.17.1 Where the operation of a protective device relies upon a power supply, an alarm is to be provided to indicate failure of the power supply, unless its failure causes automatic tripping of the protected circuit.

7.18 Testing

7.18.1 Tests in accordance with *Pt 16, Ch 2, 7.18 Testing 7.18.2* are to be satisfactorily carried out on all assemblies, complete or in sections, at the manufacturer's premises, and a test report issued by the manufacturer.

7.18.2 A high voltage test, *see Pt 16, Ch 2, 21 Testing and trials*.

7.18.3 Calibration of protective devices and indicating instruments is to be verified by means of current and/or voltage injection.

7.18.4 Demonstration of the satisfactory operation of protection circuits, control circuits and interlocks by means of simulated functional tests.

7.18.5 For switchgear and controlgear assemblies, for rated voltages above 1 kV, type tests are to be carried out, in accordance with Annex A of IEC 62271-200 -2011: *High-voltage switchgear and controlgear – Part 200: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV* and **IAC** (internal arc classification) assigned, to verify that the assembly will withstand the effects of an internal arc occurring within the enclosure at a prospective fault level equal to, or in excess of, that of the installation.

7.19 Disconnectors and switch-disconnectors

7.19.1 Disconnectors, switch-disconnectors and their components are to comply with one of the following standards, amended where necessary for ambient temperature and other environmental conditions:

(a) IEC 60947-3:*Low-voltage switchgear and controlgear – Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units*;
(b) IEC 62271-102:*High-voltage switchgear and controlgear – Part 102: Alternating current disconnectors and earthing switches*;
(c) Acceptable and relevant National Standard.

Type test reports to verify the characteristics of a disconnector or switch-disconnector are to be submitted for consideration when required.

■ *Section 8*
Protection of personnel from hazards resulting from electric arcs within electrical equipment assemblies and enclosures

8.1 General

8.1.1 An assessment is to be carried out in accordance with *Pt 16, Ch 2, 8.2 Hazard identification and assessment 8.2.1* for all electrical equipment within which an arcing fault could occur, such as:

- harmonic filters;
- motor starter panels;
- semiconductor converters;
- switchboards, section boards and distribution boards; or
- transformers.

8.2 Hazard identification and assessment

8.2.1 An assessment is to be carried out to identify the hazards and their consequences for personnel resulting from electric arcs within the electrical equipment identified in *Pt 16, Ch 2, 8.1 General 8.1.1*. The purpose of the assessment is to demonstrate that the design incorporates adequate measures to reduce the risk of injury to personnel should an arcing fault occur within the electrical equipment, and that this will help to ensure both personnel and ship safety. Details of the following are to be submitted:

(a) each task to be performed, e.g. switching, equipment maintenance, instrument observation or cleaning;
(b) the hazards to personnel that could result from an electric arc occurring during each task, and the hazards to personnel that could result from the electric arc;
(c) the methods to be used to help to prevent electric arcs; and
(d) the methods to be used to protect personnel from hazards resulting from electric arcs within electrical equipment.

8.3 Calculations to be submitted

8.3.1 The following calculations are to be conducted and used in the hazard identification and assessment:

(a) Calculations of the maximum current that would flow through an electric arc between each conductor and its adjacent conductor, and between each conductor and the exposed conductive parts of the enclosure, in the case of an arcing fault;
(b) The maximum incident energy at the intended working distance in the case of an arcing fault; and
(c) The distance from each conductor at which the incident energy would be 5 Joules (1,2 calories) per centimetre squared in the case of an arcing fault when the enclosure door is open.

These calculations may be made in accordance with a relevant Standard acceptable to LR, for example, IEEE Standard 1584, *IEEE Guide for Performing Arc-Flash Hazard Calculations*.

8.4 Testing and trials

8.4.1 It is to be demonstrated that, where provided, arrangements to detect arcing faults function correctly.

Section 9
Rotating machines

9.1 General requirements

9.1.1 In addition to the requirements of this Section, rotating machines are to comply with the relevant requirements of the following standards, amended where necessary for ambient temperature, *see Pt 16, Ch 2, 1.9 Ambient reference and operating conditions*:

(a) IEC 60034 *Rotating electrical machines* (all parts); and
(b) IEC 60092 *Electrical installations in ships* (all parts); or
(c) an alternative International or National Standard acceptable to LR.

9.1.2 The insulation systems of electrical rotating machines used for essential services are to be tested following the principles detailed in IEC 60505*, Evaluation and qualification of electrical insulations systems*, or an equivalent National Standard acceptable to LR.

9.1.3 For all the rotating machines a manufacturer's test certificate is to be provided, *see also Pt 16, Ch 2, 1.4 Surveys*.

9.1.4 All machines of 100 kW and over, intended for essential services, are to be surveyed by the Surveyor during manufacture and test, *see also Pt 16, Ch 2, 1.4 Surveys 1.4.5*.

9.1.5 Shaft materials for rotating machines for essential services are to comply with the *Rules for the Manufacture, Testing and Certification of Materials, July 2021* and be manufactured under LR survey for the following applications:

(a) shaft material for dynamic positioning and electric propulsion motors;
(b) shaft material for main engine driven generators where the shaft is part of the propulsion shafting; and
(c) shaft material for machines with power ratings of 250 kW or greater.

Shaft material for machines with power ratings less than 250 kW is to have a manufacturer's certificate as detailed in *Ch 1 General Requirements* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2021*.

9.1.6 Where welding is applied to shafts of machines for securing arms or spiders, stress relieving is to be carried out after welding. The finalized assembly is to be visually examined by the Surveyors, crack detection carried out by an appropriate method and the finished welds found sound and free from cracks.

9.1.7 The rotating parts of machines are to be so balanced that when running at any speed in the normal working range the vibration does not exceed the levels of IEC 60034-14: *Rotating electrical machines – Part 14: Mechanical vibration of certain machines with shaft heights 56 mm and higher – Measurement, evaluation and limits of vibration severity*.

9.1.8 The lubrication arrangement for bearings are to be effective under all operating conditions including the maximum craft inclinations defined by *Pt 16, Ch 2, 1.10 Inclination of craft* and there are to be effective means provided to ensure that lubricant does not reach the machine windings or other conductors and insulators.

9.1.9 Means are to be taken to prevent the ill effects of the flow of currents circulating between the shaft and machine bearings or bearings of connected machinery.

9.1.10 Alternating current machines are to be constructed such that, under any operating conditions, they are capable of withstanding the effects of a sudden short-circuit at their terminals without damage.

9.1.11 For high voltage rotating machines used for essential services are to comply with the relevant requirements of *Pt 6, Ch 2, 1 General requirements* and *Pt 6, Ch 2, 9 Rotating machines* of the *Rules and Regulations for the Classification of Ships, July 2021*.

9.1.12 The entity responsible for assembling the alternating current generating set is to install a rating plate marked with at least the following information:

(a) the generating set manufacturer's name or mark;
(b) the set serial number;
(c) the set date of manufacture (month/year);
(d) the rated power (both in kW and kVA) with one of the power rating prefixes COP, PRP (or, only for emergency generating sets, LTP) as defined in ISO 8528-1 *Reciprocating internal combustion engine driven alternating current generating sets*;
(e) the rated power factor;

(f) the set rated frequency (Hz);
(g) the set rated voltage (V);
(h) the set rated current (A); and
(i) the mass (kg).

9.2 Rating

9.2.1 Generators, including their excitation systems, and continuously rated motors are to be suitable for continuous duty at their full rated output at maximum cooling air or water temperature for an unlimited period, without the limits of temperature rise in *Pt 16, Ch 2, 9.3 Temperature rise* being exceeded. Generators are to be capable of an overload power of not less than 10 per cent at their rated power factor for a period of 15 minutes without injurious heating. Other machines are to be rated in accordance with the duty which they have to perform and, when tested under rated load conditions, the temperature rise is not to exceed the values in *Pt 16, Ch 2, 9.3 Temperature rise*.

9.2.2 When a rotating machine is connected to a supply system with harmonic distortion the rating of the machine is to allow for the increased heating effect of the harmonic loading.

9.2.3 The design and construction of smoke extraction fan motors are to be suitable for the ambient temperature and operating time required. Type test reports to verify the performance of the electric motor are to be submitted for consideration.

9.3 Temperature rise

9.3.1 The limits of temperature rise specified in *Table 2.9.1 Limits of temperature rise of machines cooled by air*, are based on the cooling air temperature and cooling water temperature given in *Pt 16, Ch 2, 1.9 Ambient reference and operating conditions*.

Table 2.9.1 Limits of temperature rise of machines cooled by air

Limits of temperature rise of machines cooled by air, °C							
Part of machine		Method of temperature measurement	Insulation class				
			A	E	B	F	H
1.	(a) a.c. windings of machines having output of 5000 kVa or more	ETD R	55 50	- -	75 70	95 90	115 110
	(b) a.c. windings of machines having output of less than 5000 kVa	ETD R	55 50	- 65	80 70	100 95	115 110
2.	Windings of armatures having commutators	R T	50 40	65 55	70 60	95 75	115 95
3.	Field windings of a.c. and d.c. machines having d.c. excitation other than those in item 4	R T	50 40	65 55	70 60	95 75	115 95
4.	(a) Field windings of synchronous machines with cylindrical rotors having d.c. excitation	R	-	-	80	100	125
	(b) Stationery field windings of d.c. machines having more than one layer	R T	50 40	65 55	70 60	95 75	115 95

	(c) Low resistance field windings of a.c. and d.c. machine and compensating windings of d.c. machines having more than one layer	R, T	50	65	70	90	115
	(d) Single-layer windings of a.c. and d.c. machines with exposed bare or varnished metal surfaces and single-layer compensating windings of d.c. machines	R, T	55	70	80	100	125
5.	Permanently short-circuited insulated windings	T	50	65	70	90	115
6.	Permanently short-circuited uninsulated windings	T	The temperature rise of these parts shall in no case reach such a value that these is a risk to any insulation or other materials on adjacent parts or to the item itself				
7.	Magnetic cores and other parts not in contact with windings	T					
8.	Magnetic cores and other parts in contact with windings	T	50	65	70	90	110
9.	Commutators and slip-rings open and enclosed	T	50	60	70	80	90
Note 1. Where water cooled heat exchangers are used in the machine cooling circuit the temperature rises are to be measured with respect to the temperature of the cooling water at the inlet to the heat exchanger and the temperature rises given in Table 2.8.1 shall be increased by 10ºC provided the inlet water temperature does not exceed the values given in *Pt 16, Ch 2, 1.9 Ambient reference and operating conditions*. Note 2. T = thermometer method R = resistance method ETD = embedded temperature detector Note 3. Temperature rise measurements are to use the resistance method whenever practicable. Note 4. The ETD method may only be used when the ETDs are located between coil sides in the slot.							

9.3.2 If it is known that the temperature of cooling medium exceeds the values given in *Pt 16, Ch 2, 1.9 Ambient reference and operating conditions* the permissible temperature rise is to be reduced by an amount equal to the excess temperature of the cooling medium.

9.3.3 If it is known that the temperature of cooling medium will be permanently less than the values given in *Pt 16, Ch 2, 1.9 Ambient reference and operating conditions* the permissible temperature rise may be increased by an amount equal to the difference between the declared temperature and that given in *Pt 16, Ch 2, 1.9 Ambient reference and operating conditions* up to a maximum of 15°C.

9.4 Generator control

9.4.1 Each alternating current generator, unless of the self-regulating type, is to be provided with automatic means of voltage regulation; voltage build-up is not to require an external source of power. Provision is to be made to safeguard the distribution system should there be a failure of the voltage regulating system resulting in a high voltage.

9.4.2 The voltage regulation of any alternating current generator with its regulating equipment is to be such that at all loads, from zero to full load at rated power factor, the rated voltage is maintained within ±2,5 per cent under steady conditions. There is to be provision at the voltage regulator to adjust the generator no load voltage.

9.4.3 Generators, and their excitation systems, when operating at rated speed and voltage on no-load are to be capable of absorbing the suddenly switched, balanced, current demand of the largest motor or load at a power factor not greater than 0,4

with a transient voltage dip which does not exceed 15 per cent of rated voltage. The voltage is to recover to rated voltage within a time not exceeding 1,5 seconds.

9.4.4 The transient voltage rise at the terminals of a generator is not to exceed 20 per cent of rated voltage when rated kVA at a power factor not greater than 0,8 is thrown off.

9.4.5 Generators and their voltage regulation systems are to be capable of maintaining, without damage, under steady state short circuit conditions a current of at least three times the full load rated current for a duration of at least two seconds or where precise data is available for the duration of any time delay which may be provided by a tripping device for discrimination purposes.

9.4.6 Generators required to run in parallel are to be stable from no load (kW) up to the total combined full load (kW) of the group, and load sharing is to be such that the load on any generator does not normally differ from its proportionate share of the total load by more than 15 per cent of the rated output (kW) of the largest machine or 25 per cent of the rated output (kW) of the individual machine, whichever is less.

9.4.7 When generators are operated in parallel, the kVA loads of the individual generating sets are not to differ from the proportionate share of the total kVA load by more than 5 per cent of the rated kVA output of the largest machines.

9.5 Overloads

9.5.1 Machines are to withstand on test, without injury, the following occasional overloads.

(a) **Generators**. An excess current of 50 per cent for 30 seconds after attaining the temperature rise corresponding to rated current, the terminal voltage being maintained as near the rated value as possible. The forgoing does not apply to the overload torque capacity of the prime mover.

(b) **Motors**. At rated speed or, in the case of a range of speeds, at the highest and lowest speeds, under gradual increase of torque, the appropriate excess torque given below. Synchronous motors and synchronous induction motors are required to withstand the excess torque without falling out of synchronism and without adjustment of the excitation circuit preset at the value corresponding to rated load:

d.c. motors	50 per cent for 15 seconds;
polyphase a.c. synchronous motors	50 per cent for 15 seconds;
polyphase a.c. synchronous induction motors	35 per cent for 15 seconds;
polyphase a.c. induction motors	60 per cent for 15 seconds.

9.6 Machine enclosure

9.6.1 Where water cooled heat exchangers are used in the machine cooling circuit there is to be provision for the detection of water leakage and the system is to be arranged so as to prevent the entry of water into the machine.

9.6.2 An alarm is to be provided to indicate high cooling water temperature.

9.7 Direct current machines

9.7.1 The final running position of brushgear is to be clearly and permanently marked.

9.7.2 Direct current machines are to work with fixed brush setting from no load to the momentary overload specified without injurious sparking.

9.8 Survey and testing

9.8.1 On machines for essential services tests are to be carried out and a certificate furnished by the manufacturer. The tests are to include temperature rise, momentary overload, high voltage, and commutation. The insulation resistance and the temperature at which it was measured are to be recorded.

9.8.2 In the case of duplicate machines, type tests of temperature rise, excess current and torque and commutation taken on a machine identical in rating and in all other essential details may be accepted in conjunction with abbreviated tests on each machine. Type tests for propulsion machines will be specially considered. For the abbreviated tests, each machine is to be run and is to be found electrically and mechanically sound and is to have a high voltage test and insulation resistance recorded.

9.8.3 A high voltage test, in accordance with *Pt 16, Ch 2, 21 Testing and trials*, is to be applied to new machines, preferably at the conclusion of the temperature rise test. Where both ends of each phase are brought out to accessible separate terminals each phase is to be tested separately.

9.8.4 An impulse test is to be carried out on the coils of high voltage machines in accordance with IEC 60034-15: *Rotating electrical machines – Part 15: Impulse voltage withstand levels of form-wound stator coils for rotating a.c. machines*, in order to demonstrate a satisfactory withstand level of the inter-turn insulation to voltage surges. The test is to be carried out on all coils after they have been inserted in the slots and after wedging and bracing. Each coil shall be subjected to at least five impulses of injected voltage, the peak value of the injected voltage being given by the formula:

$$V_{\text{peak}} = 2{,}45V$$

where

V = rated line voltage r.m.s.

Alternative proposals to demonstrate the withstand level of inter-turn insulation will be considered.

■ *Section 10* Converter equipment

10.1 Transformers

10.1.1 Paragraphs *Pt 16, Ch 2, 10.1 Transformers 10.1.2* to *Pt 16, Ch 2, 10.1 Transformers 10.1.12* apply to transformers rated for 5 kVA upwards.

10.1.2 Transformers are to comply with the requirements of the following standards:

(a) IEC 60076 (all parts): *Power transformers* (all parts);

(b) IEC 60092-503: *Electrical installations in ships – Part 503: Special features – AC supply systems with voltages in the range of above 1 kV up to and including 15 kV;* or

(c) an acceptable and relevant National Standard amended where necessary for ambient temperature, *see Pt 16, Ch 2, 1.9 Ambient reference and operating conditions*.

10.1.3 Transformers may be of the dry type, encapsulated or liquid filled type.

10.1.4 The temperature rise of the winding of transformers above the ambient temperatures given in *Pt 16, Ch 2, 1.9 Ambient reference and operating conditions*, when measured by resistance during continuous operation at the maximum rating, is not to exceed:

(a) For dry type transformers, air cooled:

- insulation of Class A - 50°C
- insulation of Class E - 60°C
- insulation of Class B - 70°C
- insulation of Class F - 90°C
- insulation of Class H - 110°C

(b) For liquid filled transformers:

- 50°C - where air provides cooling of the fluid
- 65°C - where water provides cooling of the fluid.

10.1.5 When a transformer is connected to a supply system with harmonic distortion, the rating of the transformer is to allow for the increased heating effect of the harmonic loading. Special attention is to be given to transformers connected for the purpose of reducing harmonic distortion.

10.1.6 The inherent regulation of transformers at their rated output is to be such that the total voltage drop to any point in the installation does not exceed that allowed by *Pt 16, Ch 2, 1.8 Quality of power supplies*.

10.1.7 Transformers, except those for motor starting, are to be double wound.

10.1.8 Liquid fillings for transformers are to be non-toxic and of a type which does not readily support combustion. Liquid filled transformers are to have a pressure relief-device with an alarm and there is to be a suitable means provided to contain any liquid which may escape from the transformer due to the operation of the relief device or damage to the tank.

10.1.9 All transformers are to be capable of withstanding for two seconds, without damage, the thermal and mechanical effects of a short-circuit at the terminals of any winding.

10.1.10 When forced cooling is used, whether air or liquid, there is to be monitoring of the cooling medium and transformer winding temperatures with an alarm should these exceed preset limits. There are to be arrangements so that the load may be reduced to a level commensurate with the cooling available.

10.1.11 When oil-immersed transformers are used, there is to be monitoring for low oil level with an alarm when pre-set limits are crossed. There are to be arrangements so that the load may be reduced to a level commensurate with the cooling available.

10.1.12 Where water cooled heat exchangers are used in transformer cooling circuits, there is to be provision for the detection of water leakage and the system is to be arranged so as to prevent the entry of water into the transformer.

10.1.13 The following tests are to be carried out on all transformers at the manufacturer's works, and a certificate of tests issued by the manufacturer, *see also Pt 16, Ch 2, 1.4 Surveys 1.4.2* and *Pt 16, Ch 2, 1.4 Surveys 1.4.3*:

(a) measurement of winding resistances, voltage ratio, impedance voltage, short circuit impedance, insulation resistance, load loss, no load loss and current;
(b) dielectric tests;
(c) temperature rise test on one transformer of each size and type; and
(d) where evidence of compliance with *Pt 16, Ch 2, 10.1 Transformers 10.1.9* is not submitted for consideration, short-circuit withstand on one transformer of each size and type.

10.2 Semiconductor converters

10.2.1 The requirements of *Pt 16, Ch 2, 10.2 Semiconductor converters 10.2.2* apply to semiconductor converters rated for 5 kW upwards.

10.2.2 Semiconductor converters are to comply with the requirements of IEC 60146 (all parts): *Semiconductor converters*, or an acceptable and relevant National Standard amended where necessary for ambient temperature, *see Pt 16, Ch 2, 1.9 Ambient reference and operating conditions*.

10.2.3 Semiconductor static power converters are to be rated for the required duty having regard to peak loads, system transients and overvoltage.

10.2.4 Converter equipment may be air or liquid cooled and is to be so arranged that it cannot remain loaded unless effective cooling is maintained. Alternatively the load may be automatically reduced to a level commensurate with the cooling available.

10.2.5 Liquid cooled converter equipment is to be provided with leakage alarms and there is to be a suitable means provided to contain any liquid which may leak from the system in order to ensure that it does not cause an electrical failure of the equipment. Where the semiconductors and other current carrying parts are in direct contact with the cooling liquid, the liquid is to be monitored for satisfactory resistivity and an alarm initiated at the relevant control station should the resistivity be outside the agreed limits.

10.2.6 Where forced cooling is used there is to be temperature monitoring of the heated cooling medium with an alarm and shutdown when the temperature exceeds a preset value.

10.2.7 Cooling fluids are to be non-toxic and of low flammability.

10.2.8 Converter equipment is to be so arranged that the semiconductor devices, fuses, control and firing circuit boards may be readily removed from the equipment for repair or replacement.

10.2.9 Test and monitoring facilities are to be provided to permit identification of control circuit faults and faulty components.

10.2.10 Protection devices fitted for converter equipment protection are to ensure that, under fault conditions, the protective action of circuit breakers, fuses or control systems is such that there is no further damage to the converter or the installation.

10.2.11 Converter equipment, including any associated transformers, reactors, capacitors and filters, if provided, is to be so arranged that the harmonic distortion, and voltage spikes, introduced into the craft's electrical system are within the limits of *Pt 16, Ch 2, 1.8 Quality of power supplies 1.8.3* or restricted to a lower level necessary to ensure that it causes no malfunction of equipment connected to the electrical installation.

10.2.12 Overvoltage spikes or oscillations caused by commutation or other phenomena, are not to result in the supply voltage waveform deviating from a superimposed equivalent sine wave by more than 10 per cent of the maximum value of the equivalent sine wave.

10.2.13 When converter equipment is operated in parallel, load sharing is to be such that under normal operating conditions overloading of any unit does not occur and the combination of paralleled equipment is stable throughout the operating range.

10.2.14 When converter equipment has parallel circuits there is to be provision to ensure that the load is distributed uniformly between the parallel paths.

10.2.15 Transformers, reactors, capacitors and other circuit devices associated with converter equipment, or associated filters, are to be suitable for the distorted voltage and current waveforms to which they may be subjected and filter circuits are to be provided with facilities to ensure that their capacitors are discharged before the circuits are energised.

10.2.16 Any regenerated power developed during the operation of converter equipment is not to result in disturbances to the supply system voltage and frequency which exceeds the limits of *Pt 16, Ch 2, 1.8 Quality of power supplies*.

10.2.17 Where control systems form an integral part of semiconductor equipment, they are to be designed and manufactured with regard to the environmental conditions to which they will be exposed in service and their performance is to be demonstrated during the test and trials programme.

10.2.18 Tests at the manufacturer's works of converter equipment and any associated reactors or filters are to include the high voltage test of *Pt 16, Ch 2, 21.1 Testing*, a temperature rise test, on one of each size and type of converter equipment, and such other tests as may be necessary to demonstrate the suitability of the equipment for its intended duty. Details of tests are to be submitted for consideration when required, *see also Pt 16, Ch 2, 1.4 Surveys 1.4.2*.

10.3 Uninterruptible power systems

10.3.1 The requirements of this sub-Section apply to all uninterruptible power systems (UPS) intended to maintain essential services or which provide emergency services. This sub-Section is in addition to the requirements of *Pt 16, Ch 2, 10.1 Transformers* and *Pt 16, Ch 2, 12 Batteries*, as applicable.

10.3.2 UPS units are to be constructed in accordance with IEC 62040 (all parts): *Uninterruptible power systems (UPS)*, or an acceptable and relevant National or International Standard.

10.3.3 The operation of a UPS is not to depend upon external services.

10.3.4 The type of UPS unit employed, whether off-line, line-interactive or on-line, is to be appropriate to the power supply requirements of the connected load equipment.

10.3.5 An external bypass, that is hardwired and manually operated, is to be provided for UPS to allow isolation of UPS for safety during maintenance and maintain continuity of load power.

10.3.6 UPS units are to be monitored and an audible and visual alarm is to be initiated in the navigating bridge or the engine control room, or an equivalent attended location for:

- power supply failure (voltage and frequency) to the connected load;
- earth fault;
- operation of battery protective device;
- battery discharge; and
- bypass in operation for on-line UPS units.

10.3.7 UPS units required to provide emergency services are to be suitably located for use in an emergency.

10.3.8 UPS units utilising valve-regulated sealed batteries may be located in compartments with standard marine or industrial electrical equipment provided that the arrangements comply with *Pt 16, Ch 2, 12.3 Location 12.3.5*. Ventilation arrangements in accordance with IEC 62040-1: *Uninterruptible power systems (UPS) – Part 1: General and safety requirements for UPS*, or an acceptable and relevant National or International Standard, may be considered to satisfy the requirements of *Pt 16, Ch 2, 12.5 Thermal management and ventilation 12.5.10*.

10.3.9 Output power is to be maintained for the duration required for the connected equipment.

10.3.10 The UPS battery capacity is, at all times, to be capable of supplying the designated loads for the time specified. Where it is proposed that additional circuits are connected to the UPS unit, details verifying that the UPS unit has adequate capacity are to be submitted for consideration, *see Pt 16, Ch 2, 1.5 Additions or alterations*.

10.3.11 On restoration of the input power, the rating of the charge unit is to be sufficient to recharge the batteries while maintaining the output supply to the load equipment.

10.3.12 Tests at the manufacturer's works or after installation on board are to include such tests necessary to demonstrate, to the Surveyor's satisfaction, the suitability of a the UPS unit for its intended duty and location. As a minimum, the following tests are required:

- a temperature rise test
- a battery capacity test;
- a ventilation rate test of both the equipment housing and the space into which it is to be located, *see also Pt 16, Ch 2, 12.5 Thermal management and ventilation*; and
- functional testing, including operation of alarms.

Details of tests are to be submitted for consideration when required, *see also Pt 16, Ch 2, 1.4 Surveys 1.4.2*.

10.3.13 Where the supply is to be maintained without a break following a power input failure, this is to be verified after installation by practical testing.

10.3.14 UPS units utilising lithium battery systems as energy storage devices are to be in accordance with the following sub-Sections of these Rules as applicable and to the recommendations of the battery manufacturer:

- *Pt 16, Ch 2, 1.2 Documentation required for design review*;
- *Pt 16, Ch 2, 12.1 General*;
- *Pt 16, Ch 2, 12.2 Design and construction*;
- *Pt 16, Ch 2, 12.3 Location*;
- *Pt 16, Ch 2, 12.4 Installation*;
- *Pt 16, Ch 2, 12.5 Thermal management and ventilation*; and
- *Pt 16, Ch 2, 21.1 Testing*.

■ *Section 11*
Electric cables, optical fibre cables and busbar trunking systems (busways)

11.1 General

11.1.1 The requirements of *Pt 16, Ch 2, 11.1 General* apply to all electric and optical fibre cables for fixed wiring unless otherwise exempted. The requirements of *Pt 16, Ch 2, 11.16 Joints and branch circuits in cable systems* apply to busbar trunking systems (busways) where they are used in place of electric cables.

11.1.2 Electric cables for fixed wiring are to be designed, manufactured and tested in accordance with the relevant IEC stated in *Table 2.11.1 Electric cables* or an acceptable and relevant National Standard.

Table 2.11.1 Electric cables

Application	IEC Standard	Title
General constructional and testing requirements	60092-350	Electrical installations in ships – Part 350: General construction and test methods of power, control and instrumentation cables for shipboard and offshore applications
Fixed power and control circuits	60092-353	Electrical installations in ships – Part 353: Power cables for rated voltages 1 kV and 3 kV
Fixed power circuits	60092–354	Electrical installations in ships – Part 354: Single- and three-core power cables with extruded solid insulation for rated voltages 6 kV (Um = 7,2 kV) up to 30 kV (Um = 36 kV)
Instrumentation, control and telecommunication circuits up to 60 V	60092-370	Shipboard and communication cables and radio frequency cables – General instrumentation, control and communication cables

Control and instrumentation circuits up to 250 V	60092-376	Electrical installations in ships – Part 376: Cables for control and instrumentation circuits 150/250 V (300 V)
Mineral Insulated	60702 (all parts)	Mineral insulated cables and their terminations with a rated voltage not exceeding 750 V

11.1.3 Details of optical fibre cables for fixed installation are to be submitted to assess compliance with applicable International or National Standards. These are to include:

- Flame retardancy;
- Fire resistance (if applicable);
- Smoke density;
- Halogen content;
- Mechanical properties;
- Suitability for use in the marine environment.

11.1.4 Electric cables for electric propulsion systems are to be Type Approved in accordance with *LR's Type Approval System Test Specification Number 3* or, alternatively, surveyed by the Surveyors during manufacture and testing to assess compliance with the applicable International or National Standards and application of an acceptable quality management system, *see also Pt 16, Ch 2, 1.4 Surveys 1.4.5*.

11.1.5 Provided that adequate flexibility of the finished cable is assured, conductors of nominal cross-section area 2,5 mm^2 and less need not be stranded.

11.1.6 Electric and optical fibre cables for non-fixed applications are to comply with a relevant National or International Standard.

11.1.7 For the purpose of this Section, pipes, conduits, trunking or any other system for the additional mechanical protection of cables are hereafter referred to under the generic name `protective casings'.

11.1.8 Electrical cables for telecommunications and data transfer are, whenever practicable, to be selected in accordance with the recommendations of IEC TR 60092- 370: *Guidance on the selection of cables for telecommunication and data transfer including radio-frequency cables*.

11.2 Testing

11.2.1 Routine tests, consisting of at least:

(a) measurement of electrical resistance of conductors;
(b) high voltage test, *see also Pt 16, Ch 2, 21 Testing and trials*;
(c) insulation resistance measurement;
(d) for high voltage cables, partial discharge tests are to be made in accordance with the requirements of IEC 60885-2: *Electrical test methods for electric cables – Part 2: Partial discharge tests* or an acceptable and relevant National Standard at the manufacturer's works prior to despatch.

Evidence of successful completion of routine tests is to be provided by the manufacturer.

11.2.2 Particular, special and type tests are to be made, when required, in accordance with the requirements of the relevant publication or National Standard referred to in *Pt 16, Ch 2, 11.1 General 11.1.2* and a test report issued by the manufacturer.

11.3 Voltage rating

11.3.1 The rated voltage of any electric cable is to be not lower than the nominal voltage of the circuit for which it is used. The maximum sustained voltage of the circuit is not to exceed the maximum voltage for which the cable has been designed.

11.3.2 Electric cables used in unearthed systems are to be suitably rated to withstand the additional stresses imposed on the insulation due to an earth fault.

11.4 Operating temperature

11.4.1 The maximum rated conductor temperature of the insulating material for normal operation is to be at least 10°C higher than the maximum ambient temperature liable to be produced in the space where the cable is installed.

11.4.2 The maximum rated conductor temperatures for normal and short-circuit operation, for the insulating materials included within the Standards referred to in *Pt 16, Ch 2, 11.1 General 11.1.2* is not to exceed the values stated in *Table 2.11.2 Maximum rated conductor temperature*.

Table 2.11.2 Maximum rated conductor temperature

Type of insulating compound	Maximum rated conductor temperature °C		
	Abbreviated designation	Normal operation	Short- circuit
Elastomeric or thermosetting:			
• Ethylene-propylene rubber or similar (EPM or EPDM)	EPR	90	250
• High modulus or hard grade ethylene propylene rubber	HEPR	90	250
• Cross-linked polyethylene	XLPE	90	250
• Cross-linked polyolefin material for halogen-free cables	HF90	90	250
• Silicon rubber	S95	95	350

11.4.3 Electric cables constructed of an insulating material not included in *Table 2.11.2 Maximum rated conductor temperature* are to be rated in accordance with the National Standard chosen in compliance with *Pt 16, Ch 2, 11.1 General 11.1.2*.

11.5 Construction

11.5.1 Electric and optical fibre cables are to be at least of a flame-retardant type. Compliance with IEC 60332- 1-2: *Tests on electric and optical fibre cables under fire conditions - Part 1-2: Test for vertical flame propagation for a single insulated wire or cable - Procedure for 1kW pre-mixed flame*, will be acceptable.

11.5.2 Exemption from the requirements of *Pt 16, Ch 2, 11.5 Construction 11.5.1* for applications such as radio frequency or digital communication systems, which require the use of particular types of cable, will be subject to special consideration.

11.5.3 Where electric or optical fibre cables are required to be of a `fire resistant type', they are in addition to be easily distinguishable and comply with the performance requirements of the appropriate part of IEC 60331: *Tests for electric cables under fire conditions - Circuit integrity*, when tested with a minimum flame application time of 90 minutes, as follows:

- IEC 60331-1: *Tests for electric cables under fire conditions – Circuit integrity – Part 1: Test method for fire with shock at a temperature of at least 830 degrees C for cables of rated voltage up to and including 0,6/1,0 kV and with an overall diameter exceeding 20 mm*;
- IEC 60331-2: *Tests for electric cables under fire conditions – Circuit integrity – Part 2: Test method for fire with shock at a temperature of at least 830 Degrees C for cables of rated voltage up to and including 0,6/1,0 kV and with an overall diameter not exceeding 20 mm*;
- IEC 60331-21: *Tests for electric cables under fire conditions – Circuit integrity – Part 21: Procedures and requirements - Cables of rated voltage up to and including 0,6/1,0 kV*;
- IEC 60331-23: *Tests for electric cables under fire conditions – Circuit integrity – Part 23: Procedures and requirements - Electric data cables*; or
- IEC 60331-25: *Tests for electric cables under fire conditions – Circuit integrity – Part 25: Procedures and requirements - Optical fibre cables*.

11.5.4 Where electric or optical fibre cables are installed in locations exposed to the weather, in damp and in wet situations, in machinery compartments, refrigerated spaces or exposed to harmful vapours including oil vapour, they are to have the conductor insulating materials or optical fibres enclosed in an impervious sheath of material appropriate to the expected ambient conditions.

11.5.5 Where electric or optical fibre cables are installed in locations which are totally submerged for extended periods of time, they are to have the conductor insulating materials or fibres enclosed in an impervious sheath of material appropriate to the expected submerged conditions and duration.

11.5.6 Where it is required that the construction of electric or optical fibre cables includes metallic sheaths, armouring or braids, they are to be provided with an overall impervious sheath or other means to protect the metallic elements against corrosion, *see also Pt 16, Ch 2, 11.8 Installation of electric cables 11.8.7* and *Pt 16, Ch 2, 11.8 Installation of electric cables 11.8.8*.

11.5.7 Where cables are installed in an area where contamination by oil is likely to occur, the oversheath is to be of an enhanced oil resistance grade.

11.5.8 Where single core electric cables are used in circuits rated in excess of 20 Amps and are armoured the armour is to be of a non-magnetic material.

11.5.9 Electric cables are to be constructed such that they are capable of withstanding the mechanical and thermal effects of the maximum short-circuit current which can flow in any part of the circuit in which they are installed, taking into consideration not only the time/current characteristics of the circuit protective device but also the peak value of the prospective short-circuit current. Where electric cables are to be used in circuits with a maximum short circuit current in excess of 70 kA, evidence is to be submitted for consideration when required demonstrating that the cable construction can withstand the effects of the short-circuit current.

11.5.10 All high voltage electric cables are to be readily identified by suitable marking.

11.6 Conductor size

11.6.1 The maximum continuous load carried by a cable is not to exceed its continuous current rating. It is to be chosen such that the maximum rated conductor temperature for normal operation for the insulation is not exceeded. In assessing the current rating the correction factors in *Pt 16, Ch 2, 11.7 Correction factors for cable current rating* may be applied as required.

11.6.2 The cross-sectional area of the conductors is to be sufficient to ensure that, under short-circuit conditions, the maximum rated conductor temperature for short-circuit operation is not exceeded, taking into consideration the time current characteristics of the circuit protective device and the peak value of the prospective short-circuit current.

11.6.3 The cable current ratings given in *Table 2.11.3 Electric cable current ratings, normal operation, based on ambient 45°C* and *Table 2.11.4 Electric cable current ratings, r.m.s. short circuit current* are based on the maximum rated conductor temperatures given in *Table 2.11.2 Maximum rated conductor temperature*. When cable sizes are selected on the basis of precise evaluation of current rating based upon experimental and calculated data, details are to be submitted for consideration. Alternative short-circuit temperature limits, other than those given in *Table 2.11.4 Electric cable current ratings, r.m.s. short circuit current*, may be applied using the data provided in:

- IEC 60724: *Short-circuit temperature limits of electric cables with rated voltages of 1kV (Um=1,2kV) and 3kV (Um=3,6kV);* or
- IEC 60986: *Short-circuit temperature limits of electric cables with rated voltages from 6kV (Um=7,2kV) and up to 30kV (Um=36kV)*.

Alternative short-circuit temperature limits provided in an acceptable and relevant National Standard may also be considered.

11.6.4 The cross-sectional area of the conductors is to be sufficient to ensure that at no point in the installation will the voltage variations stated in *Pt 16, Ch 2, 1.8 Quality of power supplies* be exceeded when the conductors are carrying the maximum current under their normal conditions of service.

11.6.5 The size of earth conductors is to comply with *Pt 16, Ch 2, 1.12 Earthing of non-current carrying parts 1.12.8*.

Table 2.11.3 Electric cable current ratings, normal operation, based on ambient 45°C

Nominal cross-section (mm^2)	Continuous r.m.s. current ratings, in amperes					
	Elastomeric (90°C)			Elastomeric or thermosetting, based on silicon rubber (95°C)		
	Single core	2 core	3 or 4 core	Single core	2 core	3 or 4 core
0,75	15	13	11	17	14	12
1	18	15	13	20	17	14
1,25	21	18	14	23	20	16
1,5	23	20	16	26	22	18
2	28	24	19	31	26	22

2,5	30	26	21	32	27	22
3,5	37	32	26	39	33	28
4	40	34	28	43	37	30
5,5	49	42	35	52	44	37
6	52	44	36	55	47	39
8	62	53	44	66	56	46
10	72	61	50	76	65	53
14	88	75	62	94	80	66
16	96	82	67	102	87	71
22	117	100	82	124	106	87
25	127	108	89	135	115	95
30	142	121	100	151	128	106
35	157	133	110	166	141	116
38	165	140	116	175	149	122
50	196	167	137	208	177	146
60	220	187	154	233	198	163
70	242	206	169	256	218	179
80	263	224	184	278	237	195
95	293	249	205	310	264	217
100	302	257	212	320	272	224
120	339	288	237	359	305	251
125	348	295	243	368	313	258
150	389	331	272	412	350	288
185	444	377	311	470	400	329
200	466	396	326	494	420	346
240	522	444	365	553	470	387
300	601	511	421	636	541	445

Table 2.11.4 Electric cable current ratings, r.m.s. short circuit current

Nominal cross-section (mm^2)	Fault current (kA) at 250°C			Fault current (kA) at 350°C		
	1 s duration	0,5 s duration	0,1 s duration	1 s duration	0,5 s duration	0,1 s duration
0,75	0,1	0,2	0,3	0,1	0,2	0,4
1	0,1	0,2	0,5	0,2	0,2	0,5
1,25	0,2	0,3	0,6	0,2	0,3	0,7
1,5	0,2	0,3	0,7	0,3	0,4	0,8
2	0,3	0,4	0,9	0,3	0,5	1,1
2,5	0,4	0,5	1,1	0,4	0,6	1,4

3,5	0,5	0,7	1,6	0,6	0,8	1,9
4	0,6	0,8	1,8	0,7	1,0	2,2
5,5	0,8	1,1	2,5	0,9	1,3	3,0
6	0,9	1,2	2,7	1,0	1,5	3,2
8	1,1	1,6	3,6	1,4	1,9	4,3
10	1,4	2,0	4,5	1,7	2,4	5,4
14	2,0	2,8	6,3	2,4	3,4	7,6
16	2,3	3,2	7,2	2,7	3,9	8,7
22	3,1	4,5	10,0	3,8	5,3	11,9
25	3,6	5,1	11,3	4,3	6,0	13,5
30	4,3	6,1	13,6	5,1	7,3	16,2
35	5,0	7,1	15,8	6,0	8,5	18,9
38	5,4	7,7	17,2	6,5	9,2	20,6
50	7,2	10,1	22,6	8,6	12,1	27,1
60	8,6	12,1	27,1	10,3	14,5	32,5
70	10,0	14,2	31,7	12,0	16,9	37,9
80	11,4	16,2	36,2	13,7	19,4	43,3
95	13,6	19,2	43,0	16,3	23,0	51,4
100	14,3	20,2	45,2	17,1	24,2	54,1
120	17,2	24,3	54,3	20,5	29,0	64,9
125	17,9	25,3	56,6	21,4	30,2	67,6
150	21,5	30,4	67,9	25,7	36,3	81,2
185	26,5	37,4	83,7	31,7	44,8	100,1
200	28,6	40,5	90,5	34,2	48,4	108,2
240	34,3	48,6	108,6	41,1	58,1	129,9
300	42,9	60,7	135,7	51,3	72,6	162,3

11.6.6 The cross-sectional area of conductors used in circuits supplying cyclic or non-continuous loads is to be sufficient to ensure that the cable's maximum rated conductor temperature for normal operation is not exceeded when the conductors are operating under their normal conditions of service, *see Pt 16, Ch 2, 11.7 Correction factors for cable current rating 11.7.4*.

11.7 Correction factors for cable current rating

11.7.1 The correction factors of *Pt 16, Ch 2, 11.7 Correction factors for cable current rating 11.7.2* provide a guide for general applications in assessing a current rating. A more precise evaluation based upon experimental and calculated data may be submitted for consideration.

11.7.2 Bunching of cables. Where more than six electric cables, which may be expected to operate simultaneously at their full rated capacity, are laid close together in a cable bunch in such a way that there is an absence of free air circulation around them, a correction factor of 0,85 is to be applied. Signal cables may be exempted from this requirement.

11.7.3 Ambient temperature. The current ratings of *Table 2.11.3 Electric cable current ratings, normal operation, based on ambient 45°C* are based on an ambient temperature of 45°C. For other values of ambient temperature the correction factors shown in *Table 2.11.5 Correction factors* are to be applied.

11.7.4 Short time duty. When the load is not continuous i.e. operates for periods of half an hour or one hour and the periods of no load are longer than three times the cable's time constant *T* in minutes, the cable's continuous rating may be increased by a duty factor, calculated in accordance with:

$$\text{Dutyfactor} = \sqrt{\frac{1,12}{1 - e^{\frac{-t_s}{T}}}}$$

When the load is not continuous, is repetitive and has periods of no-loads less than three times the cable's time constant, so that the cable has insufficient time to cool down between the applications of load, the cable's continuous rating may be increased by an intermittent factor, calculated in accordance with:

$$\text{Intermittentfactor} = \sqrt{\frac{1 - e^{\frac{-t_p}{T}}}{1 - e^{\frac{-t_s}{T}}}}$$

where

T = $0,245d^{1,35}$ where *d* is the overall diameter of the cable, in mm

t_s = the service time of the load current in minutes

t_p = the intermittent period in minutes, i.e. the total period of load and no-load before the cycle is repeated.

Table 2.11.5 Correction factors

Insulation material	Correction factor for ambient air temperature of °C										
	35	40	45	50	55	60	65	70	75	80	85
Elastomeric or thermosetting (90°C)	1,10	1,05	1,00	0,94	0,88	0,82	0,74	0,67	0,58	0,47	—
Elastomeric or thermosetting, based on silicone rubber (90°C)	1,10	1,05	1,00	0,95	0,89	0,84	0,77	0,71	0,63	0,55	0,45

11.7.5 Diversity. Where cables are used to supply two or more final sub-circuits account may be taken of any diversity factors which may apply, *see Pt 16, Ch 2, 5.6 Diversity factor*.

11.8 Installation of electric cables

11.8.1 Electric and optical fibre cable runs are to be as far as practicable fixed in straight lines and in accessible positions.

11.8.2 Bends in fixed electric and optical fibre cable runs are to be in accordance with the cable manufacturer's recommendations. The minimum internal radius of bend for the installation of fixed electric cables is to be chosen according to the construction and size of the cable and is not to be less than the values given in *Table 2.11.6 Minimum internal radii of bends in cables for fixed wiring*.

11.8.3 The installation of electric and optical fibre cables across expansion joints in any structure is to be avoided. Where this is not practicable, a loop of electric cable of length sufficient to accommodate the expansion of the joint is to be provided. For electric cables, the internal radius of the loop is to be at least 12 times the external diameter of the cable. For optical fibre cables, the internal radius of the loop is to meet the manufacturer's minimum recommendations.

11.8.4 Electric and optical fibre cables for essential and emergency services are to be arranged, so far as is practicable, to avoid galleys, machinery spaces and other enclosed spaces and areas of high fire risk except as is necessary for the service being supplied. Such cables are also, so far as reasonably practicable, to be routed clear of bulkheads to preclude their being rendered unserviceable by heating of the bulkheads that may be caused by a fire in an adjacent space.

11.8.5 Electric cables having insulating materials with different maximum rated conductor temperatures are to be so installed that the maximum rated conductor temperature for normal operation of each cable is not exceeded.

11.8.6 Electric and optical fibre cables having a protective covering which may damage the covering of other cables are not to be bunched with those other cables.

Table 2.11.6 Minimum internal radii of bends in cables for fixed wiring

Cable construction		Overall diameter of cable	Minimum internal radius of bend (times overall diameter of cable)
Insulation	Outer covering		
Elastomeric 600/1000 V and below	Metal sheathed Armoured and braided	Any	6D
	Other finishes	≤ 25 mm	4D
		> 25 mm	6D
Mineral	Hard metal sheathed	Any	6D
Elastomeric above 600/1000 V			
- single core	Any	Any	12D
- multicore	Any	Any	9D

11.8.7 Cables having an exposed metallic screen, braid or armour are to be installed in such a manner that galvanic corrosion by contact with other metals is prevented. Sufficient measures are also to be taken to prevent damage to exposed galvanised coatings during installation.

11.8.8 Protection is to be provided for cable oversheaths in areas where cables are likely to be exposed to damaging substances under normal circumstances or areas where the spillage or release of harmful substances is likely.

11.8.9 Electric and optical fibre cables are to be as far as practicable installed remote from sources of heat. Where installation of cables near sources of heat cannot be avoided and where there is consequently a risk of damage to the cables by heat, suitable shields, insulation or other precautions are to be installed between the cables and the heat source. The free air circulation around the cables is not to be impaired.

11.8.10 Where electric and optical fibre cables are installed in bunches, provision is to be made to limit the propagation of fire. This requirement is considered satisfied when cables of the bunch have been tested in accordance with the requirements of IEC 60332-3-22:*Tests on electric and optical fibre cables under fire conditions – Part 3-22:Test for vertical flame spread of vertically-mounted bunched wires or cables - Category A*, and are installed in the same configuration(s) as are used for the test(s). If the cables are not so installed, information is to be submitted to demonstrate satisfactorily that suitable measures have been taken to ensure that an equivalent limit of fire propagation will be achieved for the configurations to be used. Particular attention is to be given to cables in:

- atria or equivalent spaces; and
- vertical runs in trunks and other restricted spaces.

In addition, cables that comply with the requirements of IEC 60332-3-22 are also required to meet the requirements of IEC 60332-1-2: *Tests on electric and optical fibre cables under fire conditions – Part 1-2: Test for vertical flame propagation for a single insulated wire or cable – Procedure for 1 kW pre-mixed flame.*

11.8.11 Electric and optical fibre cables are not to be coated or painted with materials which may adversely affect their sheath or their fire performance.

11.8.12 Where electric and optical fibre cables are installed in refrigerated spaces they are not to be covered with thermal insulation but may be placed directly on the face of the refrigeration chamber, provided that precautions are taken to prevent the electric cables being used as casual means of suspension.

11.8.13 All metal coverings of electric and optical fibre cables are to be earthed in accordance with *Pt 16, Ch 2, 1.12 Earthing of non-current carrying parts*.

11.8.14 High voltage cables may be installed as follows:

(a) in the open, e.g. on carrier plating, when they are to be provided with a continuous metallic sheath or armour which is effectively bonded to earth to reduce danger to personnel. The metallic sheath or armour may be omitted provided that the

cable sheathing material has a longitudinal electric resistance high enough to prevent sheath currents which may be hazardous to personnel;

(b) contained in earthed metallic protective casings when the cables may be as in (a) or the armour or metal sheath may be omitted. In the latter case care is to be taken to ensure that protective casings are electrically continuous and that short lengths of cable are not left unprotected.

11.8.15 High voltage electric cables are not to be run in the open through accommodation spaces.

11.8.16 High-voltage electric cables are to be segregated from electric cables operating at lower voltages.

11.8.17 a.c. wiring is to be carried out using multicore cables wherever reasonably practicable. Where it is necessary to install single core electric cables for alternating current circuits in excess of 20 Amps the requirements of *Pt 16, Ch 2, 11.14 Single core electric cables for alternating current* are to be complied with, *see also Pt 16, Ch 2, 11.5 Construction 11.5.8*.

11.8.18 Electric and optical fibre cables are to be, so far as reasonably practicable, installed remote from sources of mechanical damage. Where necessary, the cables are to be protected in accordance with the requirements of *Pt 16, Ch 2, 11.9 Mechanical protection of cables*.

11.8.19 Electric and optical fibre cables, with the exception of those for portable appliances and those installed in protective casings, are to be fixed securely in accordance with the requirements of *Pt 16, Ch 2, 11.10 Cable support systems*.

11.8.20 Electric and optical fibre cables serving any essential services and any glands through which they pass must be able to withstand flooding for a period of 36 hours, based on the water pressure that may occur at the location.

11.8.21 Where electric and optical fibre cables penetrate bulkheads and decks, the requirements of *Pt 16, Ch 2, 11.11 Penetration of bulkheads and decks by cables* are to be complied with.

11.8.22 Where electric and optical fibre cables are installed in protective casings, the requirements of *Pt 16, Ch 2, 11.12 Installation of electric and optical fibre cables in protective casings* are to be complied with.

11.9 Mechanical protection of cables

11.9.1 Where electric cables are exposed to risk of mechanical damage they are to be protected by suitable protective casings unless the protective covering (e.g. armour or sheath) is sufficient to withstand the possible cause of damage.

11.9.2 Electric cables installed in spaces where there is exceptional risk of mechanical damage such as holds, storage spaces, cargo spaces, etc. are to be suitably protected by metallic protective casings, even when armoured, unless the craft's structure affords adequate protection.

11.9.3 Metal protective casings are to be efficiently protected against corrosion, and effectively earthed in accordance with *Pt 16, Ch 2, 1.12 Earthing of non-current carrying parts*.

11.10 Cable support systems

11.10.1 Electric cables are to be effectively supported and secured, without being damaged, to the craft's structure, either indirectly by a cable support system, or directly by means of clips, saddles or straps to bulkheads etc. *see Pt 16, Ch 2, 11.8 Installation of electric cables 11.8.4*.

11.10.2 Cable support systems, which may be in the form of trays or plates, separate support brackets, hangers or ladder racks, together with their fixings and accessories, are to be robust and are to be of corrosion-resistant material or suitably corrosion inhibited before erection. The cable support system is to be effectively secured to the craft's structure, the spacing of the fixings taking account of the probability of vibration and any heavy external forces, e.g. where located in areas subject to impact by sea-water.

11.10.3 The distances between the points at which the cable is supported (e.g. distances between ladder rungs, support brackets, hangers, etc.) are to be chosen according to the construction of cable (i.e. size and rigidity) and the probability of vibration and are to be generally in accordance with those given in *Table 2.11.7 Maximum spacing of supports or fixings for securing cables*.

Table 2.11.7 Maximum spacing of supports or fixings for securing cables

External diameter of cable		Non-armoured cables	Armoured cables
Exceeding	Not exceeding		

mm	mm	mm	mm
-	8	200	250
8	13	250	300
13	20	300	350
20	30	350	400
30	-	400	450

11.10.4 Where the cables are laid on top of their support system, the spacings of fixings may be increased beyond those given in *Table 2.11.7 Maximum spacing of supports or fixings for securing cables*, but should take account of the probability of movement and vibration and in general is not to exceed 900 mm. This relaxation is not to be applied where cables can be subjected to heavy external forces, e.g. where they are run on, or above, open deck or in areas subject to impact by sea-water.

11.10.5 Single core electric cables are to be firmly fixed, using supports of strength adequate to withstand forces corresponding to the values of the peak prospective short-circuit current.

11.11 Penetration of bulkheads and decks by cables

11.11.1 Where electric or optical fibre cables pass through watertight, fire insulated or gas tight bulkheads, the arrangements are to be such as to ensure the integrity of the bulkhead or deck is not impaired. The arrangements chosen are to ensure that the cables are not adversely affected.

11.11.2 Where cables pass through non-watertight bulkheads or structural steel, the holes are to be bushed with suitable material. If the steel is at least 6 mm thick, adequately rounded edges may be accepted as the equivalent of bushing.

11.11.3 Electric and optical fibre cables passing through decks are to be protected by deck tubes or ducts.

11.11.4 Where cables pass through thermal insulation they are to do so at right angles, in tubes sealed at both ends.

11.11.5 A schedule of watertight cable penetrations is to be prepared by the shipbuilder in either hard copy or digitised media. The schedule is to record for each type of penetration installed the following details:

(a) the marking or identification system used;
(b) the manufacturer's installation drawings and manual(s);
(c) the Type Approval certification;
(d) the as built condition of the penetration after the final inspection in the shipyard; and
(e) any inspection, modification, repair, and maintenance activities conducted.

11.12 Installation of electric and optical fibre cables in protective casings

11.12.1 Protective casings are to be mechanically continuous across joints and effectively supported and secured to prevent damage to the electric or optical fibre cables.

11.12.2 Protective casings are to be suitably smooth on the interior and have their ends shaped or bushed in such a manner as not to damage the cables.

11.12.3 The internal radius of bends of protective casings are to be not less than that required for the largest cable installed therein, *see Pt 16, Ch 2, 11.8 Installation of electric cables 11.8.2*.

11.12.4 The space factor (ratio of the sum of the cross sectional areas corresponding to the external diameters of the cables to the internal cross sectional area of the protective casings) is not to exceed 0,4.

11.12.5 Cable support systems manufactured of plastics materials installed on the open deck are to be protected from degradation caused by exposure to solar radiation.

11.12.6 Single core electric cables are to be firmly fixed, using supports of strength adequate to withstand forces corresponding to the values of the peak prospective short-circuit current.

11.12.7 Protective casings containing high voltage electric cables are not to contain other electric or optical fibre cables and are to be clearly identified, defining their function and voltage.

11.13 Non-metallic cable support systems, protective casings and fixings

11.13.1 Where it is proposed to use non-metallic cable support systems, protective casings or fixings, the additional requirements of this sub-Section apply. For high voltage installations, metallic protective casings are required where *Pt 16, Ch 2, 11.8 Installation of electric cables 11.8.14.(b)* applies.

11.13.2 Non-metallic cable support systems and protective casings are to be installed in accordance with the manufacturer's recommendations. The support systems and protective casings are to have been tested in accordance with an acceptable test procedure for:

(a) ambient operating temperatures;
(b) safe working load;
(c) impact resistance;
(d) flame retardancy;
(e) smoke and toxicity; and
(f) use in explosive gas atmospheres or in the presence of combustible dusts, electrical conductivity;

with satisfactory results.

11.13.3 Non-metallic cable support systems, protective casings and fixings installed on the open deck are to be protected from degradation caused by exposure to solar radiation.

11.13.4 Where the cable support system, protective casing or fixings are manufactured from a material other than metal, suitable supplementary metallic fixings or straps spaced at regular distances are to be provided such that, in the event of a fire or failure, the cable support system, protective casing and the affixed cables are prevented from falling and causing an injury to personnel and/or an obstruction to any escape route. Alternatively, the cables may be routed away from such areas.

11.13.5 The load on non-metallic cable support systems or protective casings is not to exceed the tested safe working load.

11.13.6 When a cable support system or protective casing is secured by means of clips or straps manufactured from a material other than metal the fixings are to be supplemented by suitable metal clips or straps spaced at regular distances each not exceeding 2 m and, for non-metallic cable support systems or protective casing, that used during safe working load testing.

11.13.7 Non-metallic fixings are to be flame retardant in accordance with the requirements of IEC 60092-101,: *Electrical installations in ships – Part 101: Definitions and general requirements*, or an alternative relevant National or International Standard.

11.14 Single core electric cables for alternating current

11.14.1 When installed in protective casings, electric cables belonging to the same circuit are to be installed in the same casing, unless the casing is of non-magnetic material.

11.14.2 Cable clips are to include electric cables of all phases of a circuit unless the clips are of non-magnetic material.

11.14.3 Single-core cables of the same circuit are to be in contact with one another, as far as possible. In any event the distance between adjacent electric cables is not to be greater than one cable diameter.

11.14.4 If single-core cables of current rating greater than 250 A are installed near a steel bulkhead, the clearance between the cables and the bulkhead is to be at least 50 mm unless the cables belonging to the same a.c. circuit are installed in trefoil formation.

11.14.5 Magnetic material is not to be used between single core cables of a group. Where cables pass through steel plates, all the conductors of the same circuit are to pass through a plate or gland, so made that there is no magnetic material between the cables, and the clearance between the cables and the magnetic material is not to be less than 75 mm, unless the cables belonging to the same a.c. circuit are installed in trefoil formation.

11.14.6 Electric cables are to be installed such that the induced voltages, and any circulating currents, in the sheath or armour are limited to safe values.

11.15 Electric cable ends

11.15.1 Where screw-clamp or spring-clamp type terminations are used in electrical apparatus for external cable connections (*see Pt 16, Ch 2, 1.11 Location and construction 1.11.7*), cable conductors of the solid or stranded type may be inserted directly into the terminals. Where flexible conductors are used, a suitable termination is to be fitted to the cable conductor to prevent 'whiskering' of the strands.

11.15.2 If compression type conductor terminations are used on the cable ends, they are to be of a size to match the conductor and to be made with a compression type tool with the dies selected to suit the termination and conductor sizes and having a ratchet action to ensure completion of the compression action.

11.15.3 Soldered sockets may be used in conjunction with non-corrosive fluxes provided that the maximum conductor temperature at the joint, under short circuit conditions, does not exceed 160°C.

11.15.4 High voltage cables of the radial field type, i.e. having a conducting layer to control the electric field within the insulation, are to have terminations which provide electrical stress control.

11.15.5 Electric cables having hygroscopic insulation (e.g. mineral insulated) are to have their ends sealed against ingress of moisture.

11.15.6 Cable terminations are to be of such a design and dimensions that the maximum current likely to flow through them will not result in degradation of the contacts or damage to insulation as the result of overheating.

11.15.7 The fixing of conductors in terminals at joints and at tappings is to be capable of withstanding the thermal and mechanical effects of short circuit currents.

11.16 Joints and branch circuits in cable systems

11.16.1 If a joint is necessary it is to be carried out so that all conductors or fibres are adequately secured, insulated and protected from atmospheric action. The flame retardant properties of the cable are to be retained, the continuity of metallic sheath, braid or armour is to be maintained and the current-carrying capacity or transmission of data through the cable is not to be impaired.

11.16.2 Tappings (branch circuits) are to be made in suitable boxes of such a design that the conductors and fibres remain suitably insulated, protected from atmospheric action and fitted with terminals or busbars of dimensions appropriate to the current rating.

11.16.3 Tappings and splices of optical fibre cables are to be made in accordance with the manufacturers' recommendations and to be provided with appropriate fittings. In addition, they are to be located within suitably designed enclosures to ensure that the protection of the optical fibres is maintained.

11.16.4 Cables of a fire-resistant type, *see Pt 16, Ch 2, 11.5 Construction 11.5.3*, are to be installed so that they are continuous throughout their length, without any joints or tappings.

11.17 Busbar trunking systems (bustrunks)

11.17.1 Where busbar trunking systems are used in place of electric cables, they are to comply with the requirements of *Pt 16, Ch 2, 11.17 Busbar trunking systems (bustrunks) 11.17.2*, in addition to the applicable requirements in *Pt 16, Ch 2, 7 Switchgear and controlgear assemblies*.

11.17.2 The busbar trunking, or enclosure system, is to have a minimum ingress protection of IP54, according to IEC60529: *Degrees of protection provided by enclosures* (IP Code).

11.17.3 The internal and external arrangements of the busbar trunking, or enclosure system, are to ensure that the fire and/or watertight integrity of any structure through which it passes is not impaired.

11.17.4 Where the busbar trunking system is employed for circuits on and below the bulkhead deck, arrangements are to be made to ensure that circuits on other decks are not affected in the event of partial flooding under the normal angles of inclination given in *Pt 16, Ch 2, 1.10 Inclination of craft* for essential electrical equipment.

11.17.5 Supports and accessories are to be robust and are to be of corrosion-resistant material or suitably corrosion inhibited before erection. The support system is to effectively secure the busbar trunking system to the craft's structure.

11.17.6 When accessories are fixed to the busbar system by means of clips or straps manufactured from a material other than metal, the fixings are to be supplemented by suitable metal clips or straps, such that, in the event of a fire or failure, the accessories are prevented from falling and causing injury to personnel and/or an obstruction to any escape route. Alternatively, the busbar system may be routed away from such areas.

Section 12
Batteries

12.1 General

12.1.1 The requirements of this Section apply to aqueous and non-aqueous permanently installed secondary batteries of the vented and valve-regulated sealed type such that the following goal and functional requirements are achieved:

- **Goal**

  Safe energy storage and dependable supply of power to consumers.
- **Functional requirements**

  Reasonably foreseeable hazards external to the battery shall be identified and managed.

  Reasonably foreseeable hazards internal within the battery shall be identified and managed.

12.1.2 A vented battery is one in which the cells have a cover provided with an opening through which the products of electrolysis and evaporation are allowed to escape freely from the cells to the atmosphere

12.1.3 A valve-regulated sealed battery is one in which the cells are closed but have an arrangement (valve) which allows the escape of gas if the internal pressure exceeds a predetermined value. The electrolyte cannot normally be replaced.

12.1.4 The following Sections apply to lead acid, nickel cadmium and lithium cell chemistries. Where other chemistries are to be used, the LR *ShipRight Procedure Assessment of Risk Based Designs* is to be followed.

12.1.5 Lithium battery systems are to satisfy the requirements of LR's *Type Approval System Test Specification Number 5 (2019)*. Alternative arrangements may be subject to special consideration.

12.1.6 Lithium battery management systems are to satisfy the requirements of LR's *Type Approval System Test Specification Number 1 (2018)*. Alternative arrangements may be subject to special consideration.

12.1.7 Where the lithium battery total system installation is less than 20 kWh then it is to be housed in a gastight steel enclosure with a gastight ventilation duct leading to a safe space on open deck and is to be suitable for withstanding the temperatures and pressures generated in the worst case thermal runaway condition. The battery system is to satisfy the requirements of LR's *Type Approval SystemTest Specification Number 5 (2019)*, or an equivalent and acceptable National or International Standard, amended where necessary for a battery space ambient temperature of 45°C. Alternative arrangements will be subject to special consideration.

12.1.8 The following Sections apply to lithium battery system installations of a total system capacity of 20 kWh or greater and are in addition to those applicable in other Parts of these Rules:

- *Pt 16, Ch 2, 12.1 General 12.1.9*;
- *Pt 16, Ch 2, 12.2 Design and construction 12.2.2* to *Pt 16, Ch 2, 12.2 Design and construction 12.2.6*;
- *Pt 16, Ch 2, 12.3 Location 12.3.12*;
- *Pt 16, Ch 2, 12.4 Installation 12.4.6* to *Pt 16, Ch 2, 12.4 Installation 12.4.10*;
- *Pt 16, Ch 2, 12.5 Thermal management and ventilation 12.5.8* and *Pt 16, Ch 2, 12.5 Thermal management and ventilation 12.5.12*;
- *Pt 16, Ch 2, 21.1 Testing 21.1.6*

12.1.9 For lithium battery system installations of nominal voltages exceeding 1500 V d.c. the LR *ShipRight Procedure Assessment of Risk Based Designs* is to be followed.

12.1.10 Additional requirements may be imposed by the National Administration with which the ship is registered and/or by the Administration within whose territorial jurisdiction the ship is intended to operate. Where any such requirements exist, in the event of a conflict with the requirements herein the requirements of the National Administration will generally take precedence.

12.1.11 Integration of a lithium battery system that satisfies a ship's main power demand into the ship's electrical power system is to be in accordance with *Pt 16, Ch 2, 23 Hybrid electrical power systems*.

12.2 Design and construction

12.2.1 Batteries are to be constructed so as to prevent spilling of the electrolyte due to motion and to minimise the emission of electrolyte spray.

12.2.2 A Failure Mode and Effects Analysis (FMEA) is to be carried out for the lithium battery system installation and is to consider the effects of failure upon safety and dependability of the lithium battery system installation taking account of reasonably foreseeable internal and external failures such that the goal and functional requirements of *Pt 16, Ch 2, 12.1 General 12.1.1* are achieved and is to include but not limited to the following:

(a) overpressure, fire and explosion;
(b) electrical short circuit due to leakage of cell electrolyte or mechanical impact;
(c) venting out flammable and toxic gases;
(d) rupture of the casing of cell, battery module, battery pack or battery system with exposure of internal components; and
(e) ingress of water into the battery space from cooling system leak, fire suppression system release and/or adjacent areas.

No single failure is to directly result in conditions more arduous than those under which the battery system has been type tested or in the hidden loss of any monitoring and control, alarm or safety function (either automatic or manual) on which the battery system installation depends for its safe operation.

12.2.3 The casing of a lithium cell and/or battery module is to incorporate a pressure relief function(s) that will prevent overpressure, rupture or explosion of the battery module enclosure (*see Pt 16, Ch 2, 21 Testing and trials*).

12.2.4 The lithium battery management system is to continuously monitor the condition of cells, battery modules or battery packs and to maintain them within their specified safe operating region. As a minimum the alarms and safeguards as indicated in *Table 2.12.1 Lithium battery system: alarms and safeguards* are to be provided:

Table 2.12.1 Lithium battery system: alarms and safeguards

Item	Alarm	Note
Cell voltage*	High	Automatic termination of the cell charge current. *See* Notes 1 and 5
	Low	Per cell. Automatic prevention of cell discharge. *See* Notes 2 and 5
Cell temperature*	1st stage high	Per sensor. *See* Notes 4 and 5
	2nd stage high	Per sensor. Automatic shutdown of battery system. *See* Notes 4 and 5
	Low	Automatic charge and discharge current limitation. *See* Notes 3 and 4
Charge current of the battery cells	High	Automatic reduction of charge/discharge current. *See* Note 3
Communication failure between battery management system and external charge controller system	Failure	Automatic shutdown of battery system *See* Note 6
Battery management system	Failure	Automatic shutdown of battery system
Temperature sensor	Failure	Automatic shutdown of battery system
Voltage sensor	Failure	Automatic shutdown of battery system
Emergency trip*	Active	Automatic shutdown of battery system. *See* Note 5

Insulation resistance	Low	-
Note 1. Cell voltage is to be maintained below the cell manufacturer specified upper limit charge voltage.		
Note 2. Cell voltage is to be maintained above the cell manufacturer specified lower limit discharge voltage.		
Note 3. Cell charge/discharge current is to be controlled within cell manufacturer specified current limits.		
Note 4. Cell temperature is to be controlled within the cell manufacturer specified temperature limits.		
Note 5. For lithium batteries used as an emergency source of power, only items marked * are to initiate automatic shutdown.		
Note 6. For lithium batteries used as an emergency source of power, communication failure is to automatically stop and prevent charging.		
Note 7. Automatic shutdown of battery system includes termination of battery charging and discharging and disconnection from electrical distribution network.		

12.2.5 A fully independent hard-wired means to disconnect the battery system in an emergency from power distribution is to be provided. This emergency trip is to be located outside of the battery space and situated such that it will remain accessible in the event of an emergency inside the battery space and is to initiate an audible and visual alarm at the relevant control stations to advise duty personnel of the emergency condition.

12.2.6 For lithium battery system installations the following is to be measured and displayed at control stations relevant to the system in which the battery system is installed:

(a) State of charge (SOC) and state of health (SOH) are to be displayed at relevant control stations and on the navigating bridge.
(b) System alarms are to be displayed at relevant control stations and at least a common alarm displayed on the navigating bridge.

12.3 Location

12.3.1 Vented batteries connected to a charging device with a power output of more than 2 kW, calculated from the maximum obtainable charging current and the nominal voltage of the battery, are to be housed in an adequately ventilated compartment assigned to batteries only, or in an adequately ventilated suitable box on open deck.

12.3.2 Vented batteries connected to a charging device with a power output within the range 0,2 kW to 2 kW, calculated from the maximum obtainable charging current and the nominal voltage of the battery, are to be installed in accordance with 11.3.1, or may be installed within a well ventilated machinery or similar space.

12.3.3 Vented batteries connected to a charging device with a power output of less than 0,2 kW, calculated from the maximum obtainable charging current and the nominal voltage of the battery, may be installed in an open position or in a battery box in any suitable space.

12.3.4 Where more than one charging device is installed for any battery or group of batteries in one location, the total power output is to be used to determine the installation requirements of *Pt 16, Ch 2, 12.3 Location 12.3.1*, *Pt 16, Ch 2, 12.3 Location 12.3.2* or *Pt 16, Ch 2, 12.3 Location 12.3.3*.

12.3.5 Valve-regulated sealed batteries may be located in compartments with standard marine or industrial electrical equipment provided that the ventilation requirements of *Pt 16, Ch 2, 12.5 Thermal management and ventilation 12.5.11* and the charging requirements of *Pt 16, Ch 2, 12.6 Charging facilities 12.6.4* and *Pt 16, Ch 2, 12.6 Charging facilities 12.6.5* are complied with. Equipment that may produce arcs, sparks or high temperatures in normal operation is not to be in close proximity to battery vent plugs or pressure relief valve outlets.

12.3.6 Where lead-acid and nickel-cadmium batteries are installed in the same compartment precautions are to be taken, such as the provision of screens, to prevent possible contamination of electrolytes.

12.3.7 Where batteries may be exposed to the risk of mechanical damage or falling objects they are to be suitably protected.

12.3.8 Batteries installed in crew and passenger cabins, together with their associated corridors, are to be of the hermetically sealed type.

12.3.9 A permanent notice prohibiting smoking and the use of naked lights or equipment, cable or creating a source of ignition, is to be prominently displayed adjacent to the entrances of all compartments containing batteries.

12.3.10 Only electrical equipment necessary for operational reasons and for the provision of lighting is to be installed in compartments provided in compliance with *Pt 16, Ch 2, 12.3 Location 12.3.1*, the compartment ventilation exhaust ducts and zones within a 1,5 m radius of the ventilation outlet(s). Such electrical equipment is to be certified for group IIC gases and

temperature Class T1 in accordance with the applicable parts of IEC 60079: *Explosive atmospheres*, or an acceptable and relevant National Standard.

12.3.11 A permanent notice is to be prominently displayed adjacent to battery installations advising personnel that replacement batteries are to be of an equivalent performance type. For valve-regulated sealed batteries, the notice is to advise of the requirement for replacement batteries to be suitable with respect to products of electrolysis and evaporation being allowed to escape from cells to the atmosphere, *see also Pt 16, Ch 2, 1.5 Additions or alterations 1.5.2*.

12.3.12 The lithium battery space is to be separate from other spaces and compartments and not to be located forward of the collision bulkhead and is not to be contiguous to the boundaries of machinery spaces of Category A or those spaces containing the main source of electrical power, associated transforming equipment (if any) or the main switchboard. The boundaries of the lithium battery space are to be part of a vessel structure or enclosures and provided with 'A-60' insulation of the bulkhead unless the space is adjacent to spaces of negligible fire risk such as cofferdams, void spaces or similar, in which case consideration may be given to reducing the insulation to 'A-0'. Penetrations through these boundaries are to be protected to the same fire protection standard. Special consideration will be made for a ship not built of steel or equivalent material. All other safety systems within the lithium battery spaces are to be in accordance with the requirements of this Section or, if not made explicit, at least equivalent to those of a machinery space of Category A.

12.4 Installation

12.4.1 Batteries are to be arranged such that each cell or crate of cells is accessible from the top and at least one side and it is to be ensured that they are suitably secured to move with the craft's motion. For high speed craft, the securing arrangements for batteries are to, as far as practicable, prevent excessive movement during the accelerations due to grounding or collision.

12.4.2 The materials used in the construction of a battery rack or stand are to be resistant to the battery electrolyte or suitably protected by paint or a coating.

12.4.3 Measures are to be taken to minimise the effect of any electrolyte spillage and leakage, for example the use of rubber capping around the top of the cells and the provision of a tray of electrolyte-resistant material below the cells, unless the deck is suitably protected with paint or a coating.

12.4.4 The interiors of all compartments for batteries, including crates, trays, boxes, shelves and other structural parts therein, are to be of an electrolyte-resistant material or suitably protected, for example with paint or a coating.

12.4.5 High speed craft are to be provided with an alarm to indicate that immediate action is required in the event of thermal runaway of any nickel cadmium or lithium battery system.

12.4.6 Battery systems are to be installed in accordance with manufacturer's recommendations taking account of the results of the FMEA study.

12.4.7 The lithium battery space and the crates, trays, boxes, shelves and other structural parts therein are to be designed and constructed such that the structural integrity of the battery space will not be compromised in the event of a lithium fire.

12.4.8 The lithium battery space is to be fitted with suitable fixed detectors in accordance with manufacturer's recommendations which are capable of providing early identification of a fire or thermal runaway condition. Early identification is to include high cell temperature or detection of electrolyte solvent vapours and a combination of smoke and heat detectors. When activated, the fire detection system is to initiate an alarm to the relevant control stations and on the navigating bridge and is to initiate the automatic isolation of electric systems within the lithium battery space except as described below, and activate the fixed fire-fighting system.

12.4.9 In the event that a fire or thermal runaway condition is identified, the battery monitoring system is to initiate protective features such as automatic safe isolation of the batteries. Ventilation necessary for extraction of gases, active cooling systems, and thermal/safety monitoring and alarm are to be continued prior to, during and after an overheating or fire event. Failure of the monitoring system is to be alarmed to the ship's safety system and is to result in the battery system automatically reverting to a defined safe state.

12.4.10 An appropriate water-based fixed fire-fighting system in accordance with SOLAS II-2, Part C, Regulation 10.4.1.1.3 and the manufacturer's recommendation is to be provided for the lithium battery space. The fixed fire-fighting system is to be suitable for heat removal, boundary cooling and/or extinguishment for the duration that the heat and/or gas release is present. Fixed fire-fighting systems using a medium other than water which provide equivalent heat removal, boundary cooling and/or extinguishment for the duration that the heat and/or gas release is present can be taken into consideration provided that appropriate fire tests have been conducted. In particular, the fire-extinguishing media are to be chosen as appropriate for the specific type and characteristics of fire foreseen.

12.4.11 The fixed fire-fighting control system is to be located outside the battery space, be activated automatically and capable of manual activation. In addition to the fixed fire-fighting system, the battery space is to be provided with a minimum of two (2) portable and suitable fire-extinguishers located outside the space at or near the entrance(s). The number and position of hydrants are to be such that at least two jets of water not emanating from the same hydrant, each from a single length of hose, can reach any part of the lithium battery space. Such hydrants are to be positioned in close proximity to the lithium battery space. Any part of the fire-fighting system which crosses through the lithium battery space without serving it, is to be avoided.

12.4.12 The fire detection and alarm systems are to be in accordance with the recommendations of the battery manufacturer and the following sub-Sections of these Rules:

- *Pt 16, Ch 1, 2.8 Fire detection and fire alarm systems*;
- *Pt 16, Ch 2, 17.1 Fire detection and fire alarm systems*;

12.4.13 The technical description detailed in *Pt 16, Ch 2, 1.2 Documentation required for design review 1.2.13.(b)* is to consider the actual battery system installation and its integration into the ship, including but not limited to the following:

- arrangement of battery compartment (location, including fire risk of adjacent spaces/compartments, fire burden from equipment other than batteries, heat sources, etc.);
- temperature control arrangements for the battery space and their contribution to system safety;
- ventilation arrangements to prevent concentrations of gasses within the space in case of uncontrolled thermal runaway;
- hazardous area(s) requirements;
- reasonable gas tightness of ventilation ducting;
- fire integrity of the space;
- the use of fire extinguishing arrangements for cooling in the case of uncontrolled thermal runaway.

The FMEA referenced in 12.2.2 should address any additional failure modes identified during the preparation of this technical description.

12.4.14 The lithium battery space is to be provided with two means of escape, at least one independent of any watertight door and leading to a safe position outside the space. One of the escapes is to be suitable for the passage of a stretcher. At each entrance/exit an emergency escape breathing device (EEBD) is to be provided. Where the maximum travel distance to the door within the lithium battery space is less than 5 m, a single means of escape is acceptable. The lithium battery space is not to be considered as part of an escape route (primary or secondary) from any other accommodation, control, service space, machinery space of Category ‘A’ and high fire risk area such as a garage, paint store, etc.

12.5 Thermal management and ventilation

12.5.1 Battery compartments and boxes are to be ventilated to avoid accumulation of dangerous concentrations of flammable gas.

12.5.2 Where a battery compartment ventilator is required to be fitted with a closing device in accordance with *Pt 3, Ch 4, 11.4 Closing appliances 11.4.1*, a warning notice clearly stating the purpose of the closing device, for example, ‘This closing device is to be kept open and only closed in the event of a fire or flooding – Explosive gas atmosphere’, is to be provided at the closing device to mitigate the possibility of inadvertent closing of the ventilator. Furthermore, means to lock battery compartment ventilators in the open position are to be provided.

12.5.3 Ducted natural ventilation may be employed for battery installations connected to a charging device with a power output of 2 kW or less, provided the exhaust duct can be run directly from the top of the compartment or box to the open air above, with no part of the duct more than 45^o from the vertical. A suitable opening is also to be provided below the level of the top of the batteries, so as to ensure a free ventilation air flow. The ventilation duct is to have an area not less than 50 cm^2 for every 1 m^3 of battery compartment or box volume.

12.5.4 Where natural ventilation is impracticable or insufficient, mechanical ventilation is to be provided, with the air inlet located near the floor and the exhaust at the top of the compartment.

12.5.5 Mechanical exhaust ventilation complying with *Pt 16, Ch 2, 12.5 Thermal management and ventilation 12.5.9* is to be provided for battery installations connected to a charging device with a total maximum power output of more than 2 kW and also, to minimise the possibility of oxygen enrichment, compartments and spaces containing batteries with boost charging facilities are to be provided with mechanical exhaust ventilation irrespective of the charging device power output.

12.5.6 The ventilation system for battery compartments and boxes, other than boxes located on open deck or in spaces to which *Pt 16, Ch 2, 12.3 Location 12.3.2*, *Pt 16, Ch 2, 12.3 Location 12.3.3* and *Pt 16, Ch 2, 12.3 Location 12.3.5* refer, is to be

separate from other ventilation systems. The exhaust ducting is to be led to a location in the open air, where any gases can be safely diluted, away from possible sources of ignition and openings into spaces where gases may accumulate.

12.5.7 Fan motors associated with exhaust ducts from battery compartments are to be placed external to the ducts and the compartments.

12.5.8 Ventilating fans for battery compartments are to be so constructed and be of material such as to minimise risk of sparking in the event of the impeller touching the casing, and are to be suitable for the potentially hazardous and corrosive gases produced in a thermal runaway condition. Non-metallic impellers are to be of an anti-static material.

12.5.9 Battery boxes are to be provided with sufficient ventilation openings located so as to avoid accumulation of flammable gas whilst preventing the entrance of rain or spray.

12.5.10 The ventilation arrangements for all installations of vented type batteries are to be such that the quantity of air expelled is at least equal to:

$$Q = 110In$$

where

n = number of cells in series

I = maximum current delivered by the charging equipment during gas formation, but not less than 25 per cent of the maximum obtainable charging current in amperes

Q = quantity of air expelled in litres/hr

12.5.11 The ventilation rate for compartments containing valve-regulated sealed batteries may be reduced to 25 per cent of that given in *Pt 16, Ch 2, 12.5 Thermal management and ventilation 12.5.10*.

12.5.12 Thermal management of the lithium battery space is to be assessed, including the criticality of any cooling systems required to ensure reliable operation and to prevent thermal runaway within the marine environment. *See also Pt 16, Ch 1, 1.3 Control, alarm and safety equipment 1.3.3*.

12.6 Charging facilities

12.6.1 Charging facilities are to be provided for all secondary batteries such that they may be completely charged from the completely discharged state in a reasonable time having regard to the service requirements.

12.6.2 Suitable means, including an ammeter and a voltmeter, are to be provided for controlling and monitoring charging of batteries, and to protect them against discharge into the charging circuits.

12.6.3 For floating circuits or any other conditions where the load is connected to the battery whilst it is on charge, the maximum battery voltage is not to exceed the safe value for any connected apparatus.

12.6.4 Where valve-regulated sealed batteries are installed, the charging facilities are to incorporate independent means such as overvoltage protection to prevent gas evolution in excess of the manufacturer's design quantity.

12.6.5 Boost charge facilities, where provided, are to be arranged such that they are automatically disconnected should the battery compartment ventilation system fail.

12.7 Recording of batteries for emergency and essential services

12.7.1 A schedule of batteries fitted for use for essential and emergency services is to be compiled and maintained.

12.7.2 Procedures are to be put in place and documented to ensure that, where batteries are replaced, they are of an equivalent performance type, *see also Pt 16, Ch 2, 1.5 Additions or alterations 1.5.3*.

12.7.3 When additions or alterations are proposed to the existing batteries for essential and emergency services, the schedule and replacement procedure documentation are to be updated to reflect the proposed installation and submitted in accordance with *Pt 16, Ch 2, 1.5 Additions or alterations 1.5.2*.

12.7.4 The schedule and replacement procedure documentation are to be made available to the LR Surveyor on request.

12.8 Cables

12.8.1 Where it is impracticable to provide electrical protective devices for certain cables supplied from batteries, e.g. within battery compartments and in engine starting circuits, unprotected cable runs are to be kept as short as possible and special

precautions should be taken to minimise risk of faults, e.g. use of single core cables with additional sleeve over the insulation of each core, with shrouded terminals.

Section 13
Equipment - Heating, lighting and accessories

13.1 Heating and cooking equipment

13.1.1 The construction of heaters is to give a degree of protection according to IEC 60529: *Degrees of protection provided by enclosures* (IP Code), or an acceptable and relevant National Standard, suitable for the intended location.

13.1.2 Heating elements are to be suitably guarded.

13.1.3 Heating and cooking equipment is to be installed such that adjacent bulkheads and decks are not subjected to excessive heating.

13.2 Lighting - General

13.2.1 Lampholders are to be constructed of flame retarding non-hygroscopic materials.

13.2.2 Lighting fittings are to be so arranged as to prevent temperature rises which overheat or damage surrounding materials. They must not impair the integrity of fire divisions.

13.3 Incandescent lighting

13.3.1 Tungsten filament lamps and lampholders are to be in accordance with *Table 2.13.1 Lamps and lampholders*.

13.3.2 Lampholders of type E40 are to be provided with a means of locking the lamp in the lampholder.

13.4 Fluorescent lighting

13.4.1 Fluorescent lamps and lampholders are to be in accordance with *Table 2.13.1 Lamps and lampholders*.

Table 2.13.1 Lamps and lampholders

Designation	Maximum lamp rating		Maximum lampholder current, A
	Voltage, V	Power, W	
Screw cap lamps			
E40	250	3000	16
E27	250	200	4
E14	250	15	2
E10	24	-	2
Bayonet cap lamps			
B22	250	200	4
B15d	250	15	2
B15s	55	15	2
Tubular fluorescent lamps			
G13	250	115	-

G5	250	80	-
Note Other lamp types are to be in accordance with IEC 60092-306: *Electrical installations in ships - Part 306: Equipment - Luminaires and lighting accessories*.			

13.4.2 Fittings, reactors, capacitors and other auxiliaries are not to be mounted on surfaces which are subject to high temperatures. If mounted separately they are additionally to be enclosed in an earthed conductive casing.

13.4.3 Where capacitors of 0,5 microfarads and above are installed, means are to be provided to promptly discharge the capacitors on disconnection of the supply.

13.5 Discharge lighting

13.5.1 Discharge lamps operating in excess of 250 V are only acceptable as fixed fittings. Warning notices calling attention to the voltage are to be permanently displayed at points of access to the lamps and where otherwise necessary.

13.6 Socket outlets and plugs

13.6.1 The temperature rise on the live parts of socket outlet and plugs is not to exceed 30°C. Socket outlets and plugs are to be so constructed that they cannot be readily short-circuited whether the plug is in or out, and so that a pin of the plug cannot be made to earth either pole of the socket outlet.

13.6.2 All socket outlets of current rating in excess of 16 A are to be provided with a switch, and be interlocked such that the plug cannot be inserted or withdrawn when the switch is in the `on' position.

13.6.3 Where it is necessary to earth the non-current carrying parts of portable or transportable equipment, an effective means of earthing is to be provided at the socket outlet.

13.6.4 On weather decks, galleys, laundries, machinery spaces and all wet situations socket outlets and plugs are to be effectively shielded against rain and spray and are to be provided with means of maintaining this quality after removal of the plug.

13.7 Enclosures

13.7.1 Enclosures for the containing and mounting of electrical accessories are to be of metal, effectively protected against corrosion, or of flame-retardant insulating materials.

■ *Section 14*
Electrical equipment for use in explosive atmospheres

14.1 General

14.1.1 Electrical equipment is not to be installed in areas where an explosive atmosphere may be present, except where necessary for operational and/or safety purposes, when the equipment is to be of a certified safe type as listed below and details of the equipment and installation are to be submitted for consideration. The construction and type testing is to be in accordance with the relevant parts of IEC 60079: *Explosive atmospheres* or an acceptable and relevant National Standard.

Intrinsically safe	-	Ex `i'
Increased safety	-	Ex `e'
Flameproof	-	Ex `d'
Pressurised enclosure	-	Ex `p'
Powder filled	-	Ex `q'
Encapsulated	-	Ex `m'

14.1.2 The installation of electrical equipment in spaces and locations in which flammable mixtures are liable to collect, e.g. areas containing flammable gas or vapour and/or combustible dust, are, to comply with the relevant requirements of *Pt 6, Ch 2,*

14 Electrical equipment for use in explosive gas atmospheres or in the presence of combustible dusts of the *Rules and Regulations for the Classification of Ships*.

14.1.3 Where cables are installed in hazardous areas, precautions are to be taken against risks being introduced in the event of an electrical fault.

14.1.4 For craft with spaces for carrying vehicles or craft with fuel in their tanks for their own propulsion, the following requirements are also applicable:

(a) electrical equipment fitted within a height of 45 cm above the vehicle deck, or any platform on which vehicles are carried, or within the exhaust ventilation trunking for the space, is to be of a safe type;
(b) electrical equipment situated elsewhere within the space is to have an enclosure of ingress protection rating of at least IP55, if not of a safe type. (*See* IEC 60529: *Degrees of protection provided by enclosures (IP Code)*). Smoke and gas detector heads are exempt from this requirement.

■ *Section 15*
Navigation and manoeuvring systems

15.1 Steering systems

15.1.1 The requirements of *Pt 16, Ch 2, 15.1 Steering systems 15.1.2* are to be read in conjunction with those in *Pt 14, Ch 1 Steering Systems*.

15.1.2 Two exclusive circuits, fed from the main source of electrical power and each having adequate capacity to supply all the motors which may be connected to it simultaneously are to be provided for each electric or electrohydraulic steering unit arrangement consisting of one or more electric motors. One of these circuits may pass through the emergency switchboard. For high speed craft, one of these circuits is to be fed either from the emergency source of electric power or from an independent power source located in such a position as to be unaffected by fire or flooding affecting the main source of power. *See also Pt 14, Ch 1, 6 Control, monitoring and electrical equipment*.

15.1.3 The main and auxiliary steering unit motors are to be capable of being started from a position on the navigating bridge and also arranged to restart automatically when power is restored after a power failure.

15.1.4 The motor of an associated auxiliary electric or electrohydraulic power unit may be connected to one of the circuits supplying the main steering unit.

15.1.5 Only short circuit protection is to be provided for each main and auxiliary steering unit motor circuit.

15.1.6 In craft of less than 1600 gross tonnage, if an auxiliary steering unit is not electrically powered or is powered by an electric motor primarily intended for other services, the main steering unit may be fed by one circuit from the main switchboard. Consideration would be given to other protective arrangements other than described in *Pt 16, Ch 2, 15.1 Steering systems 15.1.5* for such a motor primarily intended for other services.

15.1.7 Each main and auxiliary steering unit electric control system which is to be operated from the navigating bridge is to be served with electric power by a separate circuit supplied from the associated steering gear power circuit, from a point within the steering unit compartment, or directly from the same section of switchboard busbars, main or emergency, to which the associated steering unit power circuit is connected. Each separate circuit is to be provided with short circuit protection only.

15.2 Thruster systems for manoeuvring

15.2.1 Where a tunnel or athwartship thruster is fitted solely for the purpose of manoeuvring, and is electrically driven, its starting and operation is not to cause the loss of any essential services.

15.2.2 In order to ensure that the thruster system is not tripped inadvertently whilst manoeuvring the craft, overload protection in the form of an alarm is to be provided for the electric motor and any associated supply converters, in lieu of tripping.

15.2.3 The thruster electric motor is not to be disconnected as part of a load management switching operation.

15.3 Navigation lights

15.3.1 Navigation lights are to be connected separately to a distribution board reserved for this purpose only and accessible to the officer of the watch. This distribution board is to be connected directly or through transformers to the emergency source of

electrical power in compliance with, for passenger craft, *Pt 16, Ch 2, 3.2 Emergency source of electrical power in passenger craft and for yachts that are 500 gt or more 3.2.7* and *Pt 16, Ch 2, 3.2 Emergency source of electrical power in passenger craft and for yachts that are 500 gt or more 3.2.7.(b).(ii)* and *Pt 16, Ch 2, 3.2 Emergency source of electrical power in passenger craft and for yachts that are 500 gt or more 3.2.7* or, for cargo craft *Pt 16, Ch 2, 3.3 Emergency source of electrical power in craft required to comply with the HSC Code 3.3.7* and *Pt 16, Ch 2, 3.3 Emergency source of electrical power in craft required to comply with the HSC Code 3.3.8.(b).(ii)* and *Pt 16, Ch 2, 3.3 Emergency source of electrical power in craft required to comply with the HSC Code 3.3.8*. An alarm is to be activated in the event of failure of a power supply from the distribution board.

15.3.2 Each navigation light is to be controlled and protected in each insulated pole by a switch and fuse or circuit-breaker mounted on the distribution board.

15.3.3 Provision is to be made on the navigating bridge for the navigation lights to be transferred to an alternative circuit fed from the main source of electrical power.

15.3.4 Each navigation light is to be provided with an automatic indicator giving audible and/or visual indication of failure of the light. If an audible device alone is fitted, it is to be connected to an independent source of supply, e.g. a battery, with means provided to test this supply. If a visual signal is used connected in series with the navigation light, means are to be provided to prevent extinction of the navigation light due to failure of the signal. The requirements of this paragraph do not apply to pilot boats, fishing boats and similar small vessels.

15.3.5 For navigation lights using light emitting diodes (consisting of multiple light sources) means to ensure that the overall luminous intensity of the navigation light is sufficient are to be provided in addition to the alarm to indicate the complete loss of the navigation light illumination required by *Pt 16, Ch 2, 15.3 Navigation lights 15.3.4*. For replacement navigation lights, *see Pt 16, Ch 2, 1.5 Additions or alterations 1.5.5*.

15.3.6 To satisfy *Pt 16, Ch 2, 15.3 Navigation lights 15.3.5*, an audible and visual alarm is to be activated to notify the Officer of the Watch that the luminous intensity of the light reduces below the level required by the IMO Convention on the International Regulations for Preventing Collisions at Sea. Alternative measures to ensure continuing acceptable performance of navigation lights using light emitting diodes may be considered that are in accordance with:

- IMO Res. MSC.253(83), *Performance Standards for Navigation Lights, Navigation Light Controllers and associated Equipment*, and
- EN 14744, *Inland navigation vessels and sea-going vessels – Navigation light*, or a relevant National or International Standard.

Where alternative measures are proposed that require periodic verification by personnel of the luminous intensity of navigation lights using light emitting diodes, details of the inspection implementation in the ships safety management system and acceptance by the National Administration requirements are to be submitted for consideration.

15.3.7 Navigation light power supply units installed to convert, control and/or monitor the distribution board power supply required by *Pt 16, Ch 2, 15.3 Navigation lights 15.3.1* above for connection to the light source(s) (e.g. for LED type navigation lights) are, in the event of a short-circuit on the unit output, are to disconnect or limit the supply to prevent further damage and activate an alarm in the event of a short-circuit on the unit output side.

15.3.8 Navigation light power supply units are to be selfchecking, detecting failures of the unit itself and activating an alarm. These are to include:

- detection of system lock-ups (program hangs);
- means to detect whether navigation light switching command input circuits or links; and
- means to detect failure of the navigation light monitoring arrangements required to provide the alarms required by *Pt 16, Ch 2, 15.3 Navigation lights 15.3.4* and *Pt 16, Ch 2, 15.3 Navigation lights 15.3.5*, as applicable.

15.3.9 The navigation light power supply failure alarms required by *Pt 16, Ch 2, 15.3 Navigation lights 15.3.1* are not to be displayed as a group alarm. Other navigation light alarms may be grouped for each navigation light where means are provided for personnel to determine the cause of the alarm. Activation of more than one of the navigation light alarms as a result of a single failure is to be prevented.

15.3.10 Any statutory requirements of the country of registration are to be complied with and may be accepted as an alternative to the above.

15.4 Navigational aids

15.4.1 Navigational aids as required by statutory regulations are to be fed from the emergency source of electrical power. *See also Pt 16, Ch 2, 3.2 Emergency source of electrical power in passenger craft and for yachts that are 500 gt or more 3.2.7* and *Pt 16, Ch 2, 3.3 Emergency source of electrical power in craft required to comply with the HSC Code 3.3.7*.

15.5 Stabilisation

15.5.1 Where the stabilisation of a craft is essentially dependent upon a single device which in turn is dependent upon a continuous supply of electrical power, the supply arrangements are to comply with *Pt 16, Ch 2, 5.2 Essential services 5.2.3*.

15.5.2 Where such systems are not dependent upon the continuous availability of electrical power, but one or more alternative systems not dependent upon the electrical supply are installed, a single circuit may be provided, with the protection and alarms required by *Pt 16, Ch 2, 5.2 Essential services 5.2.3*.

■ *Section 16*
Electric propulsion

16.1 General

16.1.1 Where electric propulsion is proposed, details are to be submitted and the arrangements will be subject to special consideration.

■ *Section 17*
Fire safety systems

17.1 Fire detection and fire alarm systems

17.1.1 Fire detection and fire alarm systems are to be in accordance with *Chapter 9 – Fixed fire detection and fire alarm systems* of the FSS Code and the requirements in this Section as applicable.

17.1.2 Fire detection and alarm systems are to be provided with at least two power supplies. One supply is to be connected to the main source of electrical power and another supply is to be connected to the emergency source of electrical power required by *Pt 16, Ch 2, 3.2 Emergency source of electrical power in passenger craft and for yachts that are 500 gt or more*, *Pt 16, Ch 2, 3.3 Emergency source of electrical power in craft required to comply with the HSC Code* or *Pt 16, Ch 2, 3.4 Emergency source of electrical power in cargo craft, patrol and pilot craft, workboats and other similar craft of 500 tons gross tonnage and above; and cargo craft, patrol and pilot craft, workboats and other similar craft less than 500 tons gross tonnage*, or an accumulator battery capable of supplying power for the same period of time as the emergency source of electrical power. All power supply feeders for fire detection and alarm systems are to be in accordance with *Pt 16, Ch 2, 11.6 Conductor size 11.6.4*.

17.1.3 Automatic changeover facilities in accordance with *Pt 16, Ch 2, 5.3 Isolation and switching 5.3.5* are to be located in, or adjacent to, the main fire-control panel. Power supply changeover is to be achieved without adverse effect. Failure of any power supply is to operate an audible and visual alarm. *See also Pt 16, Ch 2, 1.14 Labels, signs and notices* and *Pt 16, Ch 2, 1.16 Operation under fire conditions*.

17.1.4 Where an accumulator battery provides a power supply, on restoration of the main source of electrical power, the rating of the charge unit is to be sufficient to recharge the battery while maintaining the output supply to the fire detection and alarm system.

17.1.5 Power supplies from the main and emergency switchboards are to be supplied by separate feeders that are reserved solely for this purpose. Where the emergency feeder for the electrical equipment used in the operation of the fixed fire detection and alarm system is supplied from the emergency switchboard, it is to be run from this switchboard to the automatic changeover switch without passing through any other switchboard.

17.1.6 A loop circuit of an addressable fire detection system, capable of remotely identifying individually each detector and manually operated call point served by the circuit, from either end of the loop, may serve spaces on both sides of the craft and on several decks, but is not to be situated in more than one main vertical or horizontal fire zone, nor is a loop circuit which covers an accommodation space, service space and/or control station to include a machinery space of Category A.

17.1.7 A loop circuit of an addressable fire detection system may comprise one or more sections of detectors and manually operated call points. Where the loop comprises more than one section, the sections are to be separated by devices which will ensure that, if a short-circuit occurs anywhere in the loop, only the affected section of detectors and manually operated call points

will be isolated from the control panel. No section of detectors and manually operated call points is in general to include more than 50 detectors.

17.1.8 For a craft other than a passenger craft where the fire detection system does not include means of remotely identifying each detector and manually operated call point individually, no section covering more than one deck within accommodation, service spaces and control stations is normally to be permitted except a section which covers an enclosed stairway. The number of enclosed spaces in each section is to be limited to the minimum considered necessary in order to avoid delay in identifying the source of fire. In no case are more than 50 spaces permitted in any section.

17.1.9 A section of fire detectors and manually operated call points is not to be situated in more than one main vertical or horizontal fire zone. Additionally, for craft required to comply with the HSC Code, a section of detectors and manually operated call points of an addressable fire detection system is neither to serve spaces on both sides of the craft nor on more than one deck, except that:

(a) a section of detectors and manually operated call points may serve spaces on more than one deck if those spaces are located in either the fore or aft end of the craft, or they constitute common spaces, occupying several decks, i.e. public spaces, enclosed stairways, etc.
(b) in craft of less than 20 m in breadth, a section of detectors and manually operated call points may serve spaces on both sides of the craft.

17.1.10 The wiring for each section of detectors and manually operated call points in an addressable fire detector system is to be separated as widely as practicable from that of all other sections on the same loop. Where practicable, no loop is to pass through a space twice. When this is not practicable, such as in large public spaces, the part of the loop which by necessity passes through the space for a second time is to be installed at the maximum possible distance from other parts of the loop.

17.2 Automatic sprinkler, fire detection and fire alarm systems

17.2.1 Any electrically driven power pump, provided solely for the purpose of continuing automatically the discharge of water from the sprinklers, is to be brought into action automatically by the pressure drop in the system before the standing fresh water charge in the pressure tank is completely exhausted.

17.2.2 For passenger craft, electrically driven sea-water pumps for automatic sprinkler systems are to be served by not less than two circuits reserved solely for this purpose, one fed from the main source of electrical power and one from the emergency source of electrical power. Such feeders are to be connected to an automatic change-over switch situated near the sprinkler pump and the switch is to be normally closed to the feeder from the main source of electrical power. No other switches are permitted in the feeders. The switches on the main and emergency switchboards are to be clearly labelled and normally kept closed.

17.2.3 The automatic alarm and detection system is to be fed by exclusive feeders from two sources of electrical power, one of which is to be an emergency source, with automatic change-over facilities located in, or adjacent to, the main alarm and detection panel.

17.2.4 Feeders for the sea-water pump and the automatic alarm and detection system are to be arranged so as to avoid galleys, machinery spaces and other enclosed spaces of high fire risk, except in so far as it is necessary to reach the appropriate switch boards. The cables are to be of a fire resistant type where they pass through such high risk areas.

17.3 Fixed water-based local application fire-fighting systems

17.3.1 Where fixed water-based local application fire-fighting system pressure sources are reliant on external power they need only be supplied by the main source of electrical power.

17.3.2 The fire detection, control and alarm systems are to be provided with an emergency source of electrical power required by *Pt 16, Ch 2, 3.2 Emergency source of electrical power in passenger craft and for yachts that are 500 gt or more*, *Pt 16, Ch 2, 3.3 Emergency source of electrical power in craft required to comply with the HSC Code* or *Pt 16, Ch 2, 3.4 Emergency source of electrical power in cargo craft, patrol and pilot craft, workboats and other similar craft of 500 tons gross tonnage and above; and cargo craft, patrol and pilot craft, workboats and other similar craft less than 500 tons gross tonnage* and are also to be connected to the main source of electrical power. Separate feeders, reserved solely for this purpose, with automatic changeover facilities located in, or adjacent to, the main control panel are to be provided.

17.3.3 Failure of any power supply is to operate an audible and visual alarm. *See also Pt 16, Ch 2, 1.15 Alarms* and *Pt 16, Ch 2, 1.16 Operation under fire conditions*.

17.3.4 Means to activate a system are to be located at easily accessible positions inside and outside the protected space. Arrangements inside the space are to be situated such that they will not be cut off by a fire in the protected areas and are suitable

for activation in the event of escape. Where it is proposed to install local activation means outside of the protected space, details are to be submitted for consideration.

17.3.5 For the electrical safety of electrical and electronic equipment in areas protected by fixed water-based local application, fire-fighting systems and adjacent areas where water may extend, the requirements of *Pt 16, Ch 2, 17.3 Fixed water-based local application fire-fighting systems 17.3.6* to *Pt 16, Ch 2, 17.3 Fixed water-based local application fire-fighting systems 17.3.10* apply.

17.3.6 As far as is practicable, electrical and electronic equipment is not to be located within protected areas or adjacent areas. The system pump, its electrical motor and the sea valve if any, may be in a protected space provided that they are outside areas where water or spray may extend.

17.3.7 High voltage equipment and their enclosures are not to be installed in protected areas or adjacent areas. For high voltage generators enclosures which cannot be fully located outside of adjacent areas due to close proximity, a technical justification, including proposed degree of protection ratings that are normally not to be lower that IP54, may be submitted for consideration that demonstrates the overall safety of the installation in the event of system operation.

17.3.8 In addition to the degree of protection requirements of *Pt 16, Ch 2, 1.11 Location and construction 1.11.1*, electrical and electronic equipment enclosures located within protected areas and within adjacent areas are to provide adequate protection in the event of system operation.

17.3.9 To demonstrate compliance with *Pt 16, Ch 2, 17.3 Fixed water-based local application fire-fighting systems 17.3.8*, evidence of the suitability of electrical and electronic equipment for use in protected areas and adjacent areas is to be submitted in accordance with *Pt 16, Ch 2, 1.2 Documentation required for design review 1.2.12*. The evidence is to demonstrate that additional precautions have been taken, where necessary, in respect of:

(a) satisfying *Pt 16, Ch 2, 17.3 Fixed water-based local application fire-fighting systems 17.3.6* and *Pt 16, Ch 2, 17.3 Fixed water-based local application fire-fighting systems 17.3.7*;
(b) personnel protection against electric shock;
(c) cooling airflow, where necessary, for equipment required to operate during system operation; and
(d) maintenance requirements for equipment before return to operation following system activation.

Any test evidence submitted is to consider the overall installation, including equipment types, system configuration and nozzles and the potential effects of airflows in the protected space.

17.3.10 The evidence required by *Pt 16, Ch 2, 17.3 Fixed water-based local application fire-fighting systems 17.3.9* is to demonstrate the safe and effective operation of the overall arrangements in the event of system operation. This evidence is to demonstrate that exposure to system spray and/or water:

- cannot result in loss of essential services (e.g. unintended activation of automatic machinery shutdown);
- cannot result in loss of availability of emergency services;
- will not affect the continued safe and effective operation of electrical and electronic equipment required to operate during the required period of system operation;
- does not present additional electrical or fire hazards; and
- would require only identified readily replaceable components to be repaired or replaced.

The installation of electrical and electronic equipment required to provide essential or emergency services in enclosures with a degree of protection less than IP44 within areas exposed to direct spray is to be acceptable to LR, and evidence of suitability is to be submitted accordingly.

17.3.11 Fixed water-based local application fire-fighting system electrically-driven pumps may be shared with:

- equivalent automatic sprinkler systems;
- equivalent main machinery space fire-fighting systems; or
- local fire-fighting systems for deep-fat cooking equipment;

provided that the shared use is accepted by the National Administration as complying with applicable Statutory Regulations and the arrangements comply with the requirements of *Pt 16, Ch 2, 17.3 Fixed water-based local application fire-fighting systems 17.3.12* to *Pt 16, Ch 2, 17.3 Fixed water-based local application fire-fighting systems 17.3.14*.

17.3.12 Shared electrically-driven sea-water pumps are to be served by not less than two circuits reserved solely for this purpose, one fed from the main source of electrical power and one from the emergency source of electrical power. Such feeders are to be connected to an automatic changeover switch situated near the pumps and the switch is to be normally closed to the

feeder from the main source of electrical power. No other switches are permitted in the feeders. The switches on the main and emergency switchboards are to be clearly labelled and normally kept closed.

17.3.13 Failure of a component in the power and control system is not to result in a reduction of the total available pump capacity below that required by any of the areas which the system is required to protect. For equivalent automatic sprinkler systems, a failure is not to prevent automatic release or reduce sprinkler pump capacity by more than 50 per cent.

17.3.14 Where fire-fighting systems share fire-fighting pumps, failure of one system is not to prevent activation of the pumps by any other system.

17.4 Fire pumps

17.4.1 When the emergency fire pump is electrically driven, the power is to be supplied by a source other than that supplying the main fire pumps. This source is to be located outside the machinery spaces containing the main fire pumps and their source of power and drive units.

17.4.2 The cables to the emergency fire pump are not to pass through the machinery spaces containing the main fire pumps and their source of power and drive units. The cables are to be of a fire resistant type where they pass through other high fire risk areas.

17.5 Fixed gas fire-extinguishing systems

17.5.1 Where there are electrically driven refrigeration units for carbon dioxide fire-extinguishing systems, one unit is to be supplied by the main source of electrical power and the other unit from the emergency source of electrical power.

17.5.2 Each electrically driven carbon dioxide refrigerating unit is to be arranged for automatic operation in the event of loss of the alternative unit.

17.5.3 Where it is required that alarms be provided to warn of the release of a fire-extinguishing medium, and these are electrically operated;

- they are to be provided with an emergency source of electrical power, as required by:
  - *Pt 16, Ch 2, 3.2 Emergency source of electrical power in passenger craft and for yachts that are 500 gt or more* or;
  - *Pt 16, Ch 2, 3.3 Emergency source of electrical power in craft required to comply with the HSC Code* or;
  - *Pt 16, Ch 2, 3.4 Emergency source of electrical power in cargo craft, patrol and pilot craft, workboats and other similar craft of 500 tons gross tonnage and above; and cargo craft, patrol and pilot craft, workboats and other similar craft less than 500 tons gross tonnage*
- also connected to the main source of electrical power, with automatic changeover facilities located in, or adjacent to, the fire-extinguishing media release panel, *see also Pt 16, Ch 2, 1.15 Alarms* and
- Failure of any power supply is to operate an audible and visual alarm, *see also Pt 16, Ch 2, 1.15 Alarms* and *Pt 16, Ch 2, 1.16 Operation under fire conditions*.

17.6 Fire safety stops

17.6.1 In order to limit the fire growth potential in every space of the craft, means for controlling the air supply to the spaces and flammable liquids within the spaces are to be provided.

17.6.2 To control air supply, a means of stopping all forced and induced draught fans, and all ventilation fans serving accommodation spaces, service spaces, control stations and machinery spaces from an easily accessible position outside of the space being served is to be provided. The position is not to be readily cut off in the event of a fire in the spaces served by the fans.

17.6.3 In passenger craft carrying more than 36 passengers, a second means of stopping ventilation fans serving accommodation spaces, service spaces and control stations is to be provided at a position as far apart from the position required by *Pt 16, Ch 2, 17.6 Fire safety stops 17.6.2* as is practicable. At both positions, the controls are to be grouped so that all fans can be stopped from either of the two positions.

17.6.4 A second means of stopping ventilation fans serving machinery spaces is to be provided at a position as far apart from the position required by *Pt 16, Ch 2, 17.6 Fire safety stops 17.6.2* as is practicable. At both positions the controls are to be grouped so that all fans are operable from either of the two positions. The means for stopping machinery space ventilation fans are to be entirely separate from the means for stopping fans serving all other spaces.

17.6.5 In passenger craft, the means of stopping machinery ventilation fans required by *Pt 16, Ch 2, 17.6 Fire safety stops 17.6.2* is to be located at the central control station which is to have safe access from the open deck. The central control station is to be provided with ventilation fan OFF status indications, together with a means for restarting the ventilation fans.

17.6.6 In passenger craft carrying 36 passengers or more with main laundries, electrically operated fire dampers fitted at the lower end of the laundry exhaust ducts required to comply with relevant statutory regulations are to be fitted with additional remote-control arrangements for shutting off the exhaust fans and supply fans and operating the fire dampers from within the space.

17.6.7 To control flammable liquids, a means of stopping all fuel oil, lubricating oil, hydraulic oil, cargo oil and thermal oil pumps oil purifiers from outside the spaces being served is to be provided. The position is not to be cut off in the event of a fire.

17.6.8 Means of cutting off all electrical power to the galley except lighting circuits, in the event of a fire, is to be provided outside the galley exits, at positions which will not readily be rendered inaccessible by such a fire.

17.6.9 Following activation of any fire safety stops, a manual reset is to be provided in order to restart the associated equipment.

17.6.10 Fire safety stop systems are to be designed on the fail-safe principle or alternatively the power supplies to, and the circuits of, the fire safety stop systems are to be continuously monitored and an alarm initiated in the event of a fault. Cables are to be of a fire-resistant type, *see Pt 16, Ch 2, 11.5 Construction 11.5.3 See also Pt 16, Ch 2, 5.2 Essential services 5.2.1*.

17.6.11 High speed craft bridge areas are to be provided with suitable emergency means to:

(a) close ventilation openings and stop ventilating machinery supplying spaces covered by fixed fire-extinguishing systems;
(b) shut off fuel supplies to machinery in main and auxiliary machinery spaces; and
(c) stop main engine(s) and auxiliary machinery.

Note These emergency means are to be sited in conjunction with the required fixed fire extinguishing system activation means.

17.6.12 Additionally, Passenger (B) high speed craft are to be provided with the means required by *Pt 16, Ch 2, 17.6 Fire safety stops 17.6.11* at one or more alternative stations separate from the bridge area. *See also Pt 16, Ch 1, 2.6 Bridge control for propulsion machinery 2.6.7*.

17.7 Fire doors

17.7.1 The electrical power required for the control, indication and alarm circuits of fire doors is to be provided by an emergency source of electrical power as required by *Pt 16, Ch 2, 3.2 Emergency source of electrical power in passenger craft and for yachts that are 500 gt or more*. In passenger craft carrying more than 36 passengers an alternative supply fed from the main source of electrical power, with automatic change-over facilities, is to be provided at the central control station. Failure of any power supply is to operate an audible and visual alarm, *see also Pt 16, Ch 2, 1.15 Alarms* and *Pt 16, Ch 2, 1.16 Operation under fire conditions*.

17.7.2 The control and indication systems for the fire doors are to be designed on the fail-safe principle with the release system having a manual reset.

17.8 Fire dampers

17.8.1 The electrical power required for the control and indication circuits of fire dampers is to be supplied from the emergency source of electrical power, *see also Pt 16, Ch 2, 1.16 Operation under fire conditions*.

17.8.2 The control and indication systems for the fire dampers are to be designed on the fail-safe principle with the release system having a manual reset.

17.8.3 In passenger craft carrying 36 passengers or more with main laundries, where electrically operated fire dampers are required to comply with relevant statutory regulations to be fitted at the lower end of exhaust ducts from any main laundries, they are to be capable of automatic and remote operation.

17.8.4 For craft required to comply with the HSC Code with galley range exhaust ducts, electrically operated fire dampers fitted in the lower or upper end of the duct are to be remotely operated and, additionally, the fire damper at the lower end of the duct is to be automatically operated.

17.9 Electrically powered air compressors for breathing air cylinders

17.9.1 In yachts that are 500 gt or more carrying more than 36 passengers where electrically powered air compressors are installed as part of the means required by the National Administration, for recharging breathing apparatus air cylinders for fire-fighter's outfits, the compressors are to be supplied by the main and emergency sources of electrical power. Details of the emergency supply electrical load, supply changeover arrangements and operation under fire conditions are to be submitted for consideration. The arrangements are to be to the satisfaction of the National Administration with which the craft is registered.

■ *Section 18*
Crew and passenger emergency safety systems

18.1 Emergency lighting

18.1.1 For the purpose of this Section emergency lighting, transitional emergency lighting and supplementary emergency lighting are hereafter referred to under the generic name `emergency lighting'.

18.1.2 Emergency lighting provided in compliance with *Pt 16, Ch 2, 3 Emergency source of electrical power* is to be arranged so that a fire or other casualty in the spaces containing the emergency source of electrical power, associated transforming equipment and the emergency lighting switchboard does not render the main lighting system inoperative.

18.1.3 The level of illumination provided by the emergency lighting is to be adequate to permit safe evacuation in an emergency, having regard to the possible presence of smoke *see Pt 16, Ch 2, 18.4 Escape route or low location lighting (LLL)*.

18.1.4 The locations identified in *SOLAS - International Convention for the Safety of Life at Sea Chapter II-1 - Construction - Structure, subdivision and stability, machinery and electrical installations*, *Part D - Electrical installations*, *Regulation 41 - Main source of electrical power and lighting systems*, *Regulation 42 - Emergency source of electrical power in passenger ships* and *Regulation 43 - Emergency source of electrical power in cargo ships*, and the exits from accommodation spaces and service spaces, as defined by *SOLAS - International Convention for the Safety of Life at Sea Chapter II-2 - Construction - Fire protection, fire detection and fire extinction*, *Part A - General Regulation 3 - Definitions* are to be illuminated by emergency lighting.

18.1.5 Switches are not to be installed in the final sub-circuits to emergency light fittings unless the light fittings are serving normally unmanned spaces, e.g. storage rooms, cold rooms, etc. or they are normally required to be extinguished for operational reasons, e.g. for night visibility from the navigating bridge. Where switches are fitted they are to be accessible only to craft crew with provision made to ensure that the emergency lighting is energised when such spaces are manned and/or during emergency conditions.

18.1.6 Where emergency lighting fittings are connected to dimmers, provision is to be made, upon the loss of the main lighting, to automatically restore them to their normal level of illumination.

18.1.7 Fittings are to be specially marked to indicate that they form part of the emergency lighting system.

18.2 General emergency alarm system

18.2.1 An electrically operated bell or klaxon or other equivalent warning system installed in addition to the craft's whistle or siren, for sounding the general emergency alarm signal, is to comply with the *International Life-saving Appliances (LSA) Code* and with the requirements of this Section, *see also Pt 16, Ch 2, 1.15 Alarms* and *Pt 16, Ch 2, 1.16 Operation under fire conditions*.

18.2.2 The general emergency alarm system is to be provided with an emergency source of electrical power as required by *Pt 16, Ch 2, 3.2 Emergency source of electrical power in passenger craft and for yachts that are 500 gt or more*, *Pt 16, Ch 2, 3.3 Emergency source of electrical power in craft required to comply with the HSC Code*, *Pt 16, Ch 2, 3.4 Emergency source of electrical power in cargo craft, patrol and pilot craft, workboats and other similar craft of 500 tons gross tonnage and above; and cargo craft, patrol and pilot craft, workboats and other similar craft less than 500 tons gross tonnage* or *Pt 16, Ch 2, 20.10 Sources of electrical power* and also connected to the main source of electrical power with automatic changeover facilities located in, or adjacent to, the main alarm signal distribution panel. Failure of any power supply is to operate an audible and visual alarm, *see also Pt 16, Ch 2, 1.15 Alarms*.

18.2.3 The general emergency alarm distribution system is to be so arranged that a fire or casualty in any one main vertical zone, as defined by SOLAS *Regulation 3 - Definitions*, other than the zone in which the public address control station is located, will not interfere with the distribution in any other such zone.

18.2.4 There are to be segregated cable routes to public rooms, alleyways, stairways, control stations and on passenger craft on open decks, so arranged that any single electrical fault, localised fire or casualty will not cause the loss of the facility to sound the general emergency alarm in any public rooms, alleyways, stairways, control stations and on passenger craft on open decks, albeit at a reduced capacity.

18.2.5 Where the special alarm fitted to summon the crew, operated from the navigation bridge, or fire control station, forms part of the craft's general alarm system, it is to be capable of being sounded independently of the alarm to the passenger spaces.

18.2.6 The sound pressure levels are to be measured during a practical test and documented, *see Pt 16, Ch 2, 21.2 Trials*.

18.3 Public address system

18.3.1 Public address systems are to comply with the *International Life-saving Appliances (LSA) Code* and the requirements of this Section.

18.3.2 The public address system is to be provided with an emergency source of electrical power as required by *Pt 16, Ch 2, 3.2 Emergency source of electrical power in passenger craft and for yachts that are 500 gt or more*, *Pt 16, Ch 2, 3.3 Emergency source of electrical power in craft required to comply with the HSC Code*, *Pt 16, Ch 2, 3.4 Emergency source of electrical power in cargo craft, patrol and pilot craft, workboats and other similar craft of 500 tons gross tonnage and above; and cargo craft, patrol and pilot craft, workboats and other similar craft less than 500 tons gross tonnage* or *Pt 16, Ch 2, 20.10 Sources of electrical power* and also connected to the main source of electrical power with automatic changeover facilities located adjacent to the public address system. Failure of any power supply is to operate an audible and visual alarm, *see also Pt 16, Ch 2, 1.15 Alarms* and *Pt 16, Ch 2, 1.16 Operation under fire conditions*.

18.3.3 The public address system is to have multiple amplifiers having their power supplies so arranged that a single fault will not cause the loss of the facility to broadcast emergency announcements in public rooms, alleyways, stairways and control stations, albeit at a reduced capacity.

18.3.4 The public address distribution system is to be so arranged that a fire or casualty in any one main vertical zone, as defined by SOLAS *Regulation 3 - Definitions*, other than the zone in which the public address control station is located, will not interfere with the distribution in any other such zone.

18.3.5 There are to be segregated cable routes to public rooms, alleyways, stairways, and control stations so arranged that any single electrical fault, fire or casualty will not cause the loss of the facility to broadcast emergency announcements in any public rooms, alleyways, stairways, and control stations, albeit at a reduced capacity.

18.3.6 Amplifiers are to be continuously rated for the maximum power that they are required to deliver into the system for audio and, where alarms are to be sounded through the public address system, for tone signals.

18.3.7 Loudspeakers are to be continuously rated for their proportionate share of amplifier output and protected against short-circuits.

18.3.8 Amplifiers and loudspeakers are to be selected and arranged to prevent feedback and other interference. There are also to be means to automatically override any volume controls, so as to ensure the specified sound pressure levels are met.

18.3.9 Where the public address system is used for sounding the general emergency alarm and the fire-alarm, the following requirements are to be met in addition to those of *Pt 16, Ch 2, 18.2 General emergency alarm system*:

(a) The emergency system is given automatic priority over any other system input.
(b) More than one device is provided for generating the sound signals for the emergency alarms.

18.3.10 Where more than one alarm is to be sounded through the public address system, they are to have recognizably different characteristics and additionally be arranged, so that any single electrical failure which prevents the sounding of any one alarm will not affect the sounding of the remaining alarms.

18.3.11 The sound pressure levels are to be measured during a practical test using speech and, where applicable, tone signals, and documented, *see Pt 16, Ch 2, 21.2 Trials*.

18.4 Escape route or low location lighting (LLL)

18.4.1 Where required escape route or low location lighting (LLL) is satisfied by electric illumination, the LLL system is to comply with the requirements of this sub-Section.

18.4.2 The LLL system is to be provided with an emergency source of electrical power and also be connected to the main source of electrical power, with automatic changeover facilities located adjacent to the control panel, *see also Pt 16, Ch 2, 1.16 Operation under fire conditions*.

18.4.3 The power supply arrangements to the LLL are to be arranged so that a single fault or a fire in any one fire zone or deck does not result in loss of the lighting in any other zone or deck. This requirement may be satisfied by the power supply circuit configuration, use of fire-resistant cables complying with *Pt 16, Ch 2, 11.5 Construction 11.5.3*, and/or the provision of suitably located power supply units having integral batteries adequately rated to supply the connected LLL for a minimum period of 60 minutes, *see Pt 16, Ch 2, 12.3 Location 12.3.7*.

18.4.4 The performance and installation of lights and lighting assemblies are to comply with ISO standard 15370: *Ships and marine technology - Low location lighting on passenger ships – Arrangement*.

■ *Section 19*
Craft safety systems

19.1 Watertight doors

19.1.1 The electrical power required for power-operated sliding watertight doors is to be separate from any other power circuit and supplied from the emergency switchboard either directly or by a dedicated distribution board situated above the waterline in the final condition of damage or above the bulkhead deck as applicable. The associated control, indication and alarm circuits are to be supplied from the emergency switchboard either directly or by a dedicated distribution board situated above the waterline in the final condition of damage or above the bulkhead deck as applicable and for passenger craft be capable of being automatically supplied by the transitional source of emergency electrical power required by *Pt 16, Ch 2, 3.2 Emergency source of electrical power in passenger craft and for yachts that are 500 gt or more 3.2.9* or, where applicable, *Pt 16, Ch 2, 3.3 Emergency source of electrical power in craft required to comply with the HSC Code 3.3.9* in the event of failure of either the main or emergency source of electrical power.

19.1.2 A single failure in the power operating or control system of power-operated sliding watertight doors is not to result in a closed door opening or prevent the hand operation of any door.

19.1.3 Availability of the power supply is to be continuously monitored at a point in the electrical circuit adjacent to the door operating equipment. Loss of any such power supply is to activate an audible and visual alarm at the central operating console at the navigating bridge.

19.1.4 Electrical power, control, indication and alarm circuits are to be protected against fault in such a way that a failure in one door circuit will not cause a failure in any other door circuit. Short circuits or other faults in the alarm or indicator circuits of a door are not to result in a loss of power operation of the door. Arrangements are to be such that leakage of water into the electrical equipment located below the bulkhead deck will not cause the door to open.

19.1.5 The enclosures of electrical components necessarily situated below the waterline in the final condition of damage or below the bulkhead deck as applicable are to provide suitable protection against the ingress of water with ratings as defined in IEC 60529: *Degrees of protection provided by enclosures (IP Code)* or an acceptable and relevant National Standard, as follows:

(a) Electrical motors, associated circuits and control components, protected to IPX7 Standard.
(b) Door position indicators and associated circuit components protected to IPX8 Standard, where the water pressure testing of the enclosures is to be based on the pressure that may occur at the location of the component during flooding for a period of 36 hours.
(c) Door movement warning signals, protected to IPX6 Standard.

19.1.6 Watertight door electrical controls including their electric cables are to be kept as close as is practicable to the bulkhead in which the doors are fitted and so arranged that the likelihood of them being involved in any damage which the craft may sustain is minimised.

19.1.7 An audible alarm, distinct from any other alarm in the area, is to sound whenever the door is closed remotely by power and sound for at least five seconds but no more than ten seconds before the door begins to move and is to continue sounding until the door is completely closed. The audible alarm is to be supplemented by an intermittent visual signal at the door in passenger areas and areas where the noise level exceeds 85 dB(A).

19.1.8 A central operating console is to be fitted on the navigating bridge and is to be provided with a `master-mode' switch having:

(a) a `local control' mode for normal use which is to allow any door to be locally opened and locally closed after use without automatic closure, and;

(b) a `doors closed' mode for emergency use which is to allow any door that is opened to be automatically closed whilst still permitting any doors to be locally opened but with automatic reclosure upon release of the local control mechanism.

19.1.9 The `master mode' switch is to be arranged to be normally in the `local control' mode position; be clearly marked as to its emergency function and be Type Approved in accordance with LR's Procedure for Type Approved Products.

19.1.10 The central operating console at the navigating bridge is to be provided with a diagram showing the location of each door, with visual indicators to show whether each door is open or closed. A red light is to indicate a door is fully open and a green light, a door fully closed. When the door is closed remotely a red light is to indicate the intermediate position by flashing. The indicating circuit is to be independent of the control circuit for each door.

19.1.11 The arrangements are to be such that it is not possible to remotely open any door from the central operating console.

19.2 Shell doors, loading doors and other closing appliances.

19.2.1 Where it is required that indicators be provided for shell doors, loading doors and other closing appliances, which are intended to ensure the watertight integrity of the craft's structure in which they are located, the indicator system is to be designed on the fail-safe principle. The system is to indicate if any of the doors or closing appliances are open or are not fully closed or secured.

19.2.2 Where such doors and appliances are to be operated at sea, the requirements of *Pt 16, Ch 2, 19.1 Watertight doors* are to be complied with as far as is practicable.

19.2.3 The electrical power supply for the indicator system is to be independent of any electrical power supply for operating and securing the doors.

■ *Section 20*
Cargo craft, patrol and pilot craft, workboats and other similar craft of less than 500 tons gross tonnage for operation in Service Groups 1 to 3, and yachts less than 500 gt

20.1 General requirements

20.1.1 The requirements of this Section are applicable to electrical installations where the voltage of supply does not exceed 440 V a.c. or d.c.

20.1.2 The electrical installations for propulsion and auxiliary service where the voltage of supply exceeds 440 volts are to be constructed and installed in accordance with *Pt 16, Ch 2, 1 General requirements*.

20.1.3 Cargo craft of 300 tons gross tonnage and above are also to comply with *Pt 16, Ch 2, 3.7 Radio installation*.

20.1.4 Alternative arrangements, including those in accordance with IEC 60092-507:*Electrical installations in ships – Part 507: Small vessels*, or a relevant International or National Standard acceptable to LR may be considered.

20.2 Plans

20.2.1 At least three copies of the plans and particulars in *Pt 16, Ch 2, 20.2 Plans 20.2.2* are to be submitted for consideration. Single copies only are required of plans in *Pt 16, Ch 2, 20.2 Plans 20.2.7*.

20.2.2 Single line diagram of main power and lighting systems which is to include:

(a) rating of machines; transformers; batteries and semi-conductor converters;
(b) all feeders connected to the main switchboard;
(c) section boards and distribution boards;
(d) insulation type, size and current loadings of cables;
(e) make, type and rating of circuit breakers and fuses.

20.2.3 Simplified diagrams of generator circuits and feeder circuits showing:

(a) protective devices;
(b) instrumentation and control devices;

(c) preference tripping;
(d) earth fault indication/protection.

20.2.4 Calculations of short circuit currents at main switchboard and distribution boards, details of circuit breaker and fuse operating times and discrimination curves.

20.2.5 For battery installation, arrangement plans and calculations are to show compliance with *Pt 16, Ch 2, 20.12 Batteries*.

20.2.6 Details of electrically operated personnel safety systems which are to include single line diagrams and a general arrangement plan of the vessel showing location and cable routes of:

(a) fire detection, alarm and extinction systems;
(b) internal communication and alarm systems.

20.2.7 Schedule of normal operating loads on the system.

20.3 Survey

20.3.1 The installation is to be inspected and tested by the Surveyors, in accordance with the requirements of *Pt 16, Ch 2, 21 Testing and trials*, as appropriate, and is to be to their satisfaction.

20.4 Addition or alterations

20.4.1 No addition, temporary or permanent is to be made to an approved installation until it has been ascertained that the current carrying capacity and the condition of the existing equipment, including cables and switchgear, are adequate for the increased load.

20.4.2 Plans are to be submitted for consideration, and the alterations or additions are to be carried out under the survey and to the satisfaction of the Surveyors.

20.5 Location and construction of equipment

20.5.1 Electrical equipment is to be accessibly placed, clear of flammable material in well ventilated, adequately lighted spaces, in which flammable gases cannot accumulate and where it is not exposed to risk of mechanical damage or damage from water, steam or oil. Where necessarily exposed to such risks, the equipment is to be suitably constructed or enclosed. Equipment is to be accessible for maintenance.

20.5.2 Insulating materials and insulated windings are to be flame retardant, and resistant to tracking, moisture, sea air and oil vapour unless special precautions are taken to protect them.

20.5.3 Securing arrangements used in connection with current carrying parts are to be effectively locked.

20.5.4 The operation of all electrical equipment is to be satisfactory under such conditions of vibrations, movements and shock as may arise in normal practice.

20.5.5 The design and installation of electrical equipment is to be such that the risk of fire due to its failure is minimised. It is, as a minimum, to comply with a National or International Standard revised where necessary for ambient conditions. Equipment is to be tested at the manufacturer's works and a certificate of tests issued by the manufacturer.

20.6 Systems of distribution

20.6.1 The following systems of generation and distribution are acceptable:

(a) two wire insulated;
(b) two wire with one pole earthed;
(c) three phase three wire insulated neutral;
(d) three phase, four wire with neutral earthed but without hull return.

20.6.2 A device(s) is to be installed for every insulated distribution system, whether primary or secondary, for power, heating and lighting circuits to continuously monitor the insulation level to earth.

20.7 Earthing

20.7.1 Except where exempted by *Pt 16, Ch 2, 20.7 Earthing 20.7.2* all non-current carrying exposed metal parts of electrical equipment and cables are to be earthed.

20.7.2 The following parts may be exempted from the requirements of *Pt 16, Ch 2, 20.7 Earthing 20.7.1*:

(a) lamp-caps, where suitably shrouded;
(b) shades, reflectors and guards supported in lampholders or light fittings constructed of, or shrouded in, non-conducting material;
(c) metal parts on, or screws in or through, non-conducting materials, which are separated by such material from current-carrying parts and from earthed non-current carrying parts in such a way that in normal use they cannot become live or come into contact with earthed parts;
(d) apparatus which is constructed in accordance with the principle of double insulation;
(e) bearing housings which are insulated in order to prevent circulation of current in the bearings;
(f) clips for fluorescent lamps;
(g) cable clips and short lengths of pipes for cable protection;
(h) apparatus supplied at a voltage not exceeding 55V direct current or 55V root mean square, between conductors, or between any conductor and earth in a circuit isolated from the supply. Autotransformers are not to be used for the purpose of achieving the alternating current voltage;
(i) apparatus or parts of apparatus which although not shrouded in insulating material is nevertheless otherwise so guarded that it cannot be touched and cannot come in contact with exposed metal.

20.7.3 With wood and other non-metallic hull constructions earthing connections are to be made to the generator frame, engine bedplate and earthing plate. Earthing connections are not to be made to hull sheathing, skin fittings or plumbing.

20.8 Protection

20.8.1 Installations are to be protected against overcurrents including short circuits. The tripping/fault clearance times of protective devices are to provide complete and co-ordinated protection to ensure:

(a) availability of services not affected by the faulty circuit;
(b) elimination of the fault to reduce damage to the system and hazard of fire.

20.8.2 Short circuit protection and a means of complete isolation is to be provided for each source of power.

20.8.3 Protection for battery circuits is to be provided at a position external and adjacent to the battery compartments; batteries used solely for engine starting may be provided with only a means of isolation.

20.8.4 Short circuit and overload protection together with a means of isolation is to be provided in each non-earthed outgoing circuit of the main switchboard and each distribution board.

20.8.5 Each final sub-circuit is to be provided with short circuit protection and a means of isolation in each non-earthed line.

20.8.6 Lighting circuits are to be supplied by circuits separate from those for power.

20.8.7 Control circuits for engine monitoring and other services are to be provided with short circuit protection.

20.8.8 Protective devices are not to be fitted in any earthed line of a distribution system.

20.8.9 Circuit breakers and fuses are to have a certified fault rating adequate for the installation and are to comply with a National or International Standard.

20.8.10 In the absence of precise data the calculation methods given in *Pt 16, Ch 2, 6.2 Protection against short-circuit 6.2.4* are to be used for evaluation of short circuit currents.

20.8.11 Generators for a.c. systems are to be provided, as a minimum, with the protective gear required by *Pt 16, Ch 2, 6.8 Protection of generators 6.8.2* and *Pt 16, Ch 2, 6.8 Protection of generators 6.8.3* and additionally provided with the instrumentation required by *Pt 16, Ch 2, 7.11 Instruments for alternating current generators*.

20.9 Quality of power supplies

20.9.1 Unless specified otherwise electrical equipment, other than that supplied by battery systems, is to operate satisfactorily with the following simultaneous variations, from their nominal value, when measured at the consumer input terminals.

(a) Voltage:

- Permanent variations +6 per cent, -10 per cent
- Transient recovery +20 per cent, -15 per cent
- Recovery time 1,5 seconds.

(b) Frequency:

- Permanent variations ±5 per cent
- Transient variations ±10 per cent
- Recovery time five seconds

20.9.2 Generator voltage regulators and engine governors are to be such as to ensure that the above supply variations are not exceeded.

20.10 Sources of electrical power

20.10.1 Under sea-going conditions where electrical power is required for services for the propulsion, navigation and safety of the craft and crew, it is to be provided by either a generator(s) having a rating sufficient to ensure the operation of these services or by an engine-driven charging system in conjunction with a battery(ies).

20.10.2 Under emergency conditions where electrical power is required for lighting to enable persons to evacuate the craft, for navigational lights, fire detection and alarm systems and internal communication and alarm systems, it is to be provided by alternative source(s) of electrical power located separately from the source(s) of power in *Pt 16, Ch 2, 20.10 Sources of electrical power 20.10.1* and suitably located for use in an emergency. This source(s) of electrical power is to be adequate to permit evacuation and to supply the navigation lights, fire detection and alarm systems and internal communication and alarm systems, for a period of 5 hours duration.

20.10.3 Where electrical power is required for services for the propulsion, navigation and safety of the yacht or craft and for the safety of the crew it is to be provided by:

(a) for **non-passenger type yachts of scantling length between 24 m and 50 m**, at least two generators having ratings sufficient to ensure the operation of these services when any one generator is out of action; or
(b) for **non-passenger type service craft for Service Groups 1 to 3**, a generator(s) having a rating sufficient to ensure the operation of these services without being overloaded.

20.10.4 Additionally, for **non-passenger type yachts of scantling length between 24 m and 50 m**:

(a) generators fitted to satisfy the requirements of *Pt 16, Ch 2, 20.10 Sources of electrical power 20.10.3* may be driven by the main engine provided the requirements of *Pt 16, Ch 2, 20.9 Quality of power supplies 20.9.1* are satisfied for all main engine speed and load conditions and that there is at least one of the remaining generators driven by a prime mover independent of the main engine; and
(b) any batteries provided for the duty, referred to in *Pt 16, Ch 2, 20.10 Sources of electrical power 20.10.2*, are to be rated for at least 5 hours duration.

20.10.5 Additionally, for **non-passenger type service craft for Service Groups 1 to 3**, in a single generator installation, or where in a multiple generator installation with one generator out of action the remaining generator(s) is not capable of supplying the circuits serving any safety, essential lighting and communication equipment, an alternative source of electrical power of 5 hours duration is to be provided for these services.

20.11 Cables

20.11.1 Cables and cable installations are to be in accordance with the requirements of *Pt 16, Ch 2, 11 Electric cables, optical fibre cables and busbar trunking systems (busways)*.

20.11.2 Where the emergency services referenced in Section 1.14 are fitted, their cables are required to be in accordance with *Pt 16, Ch 2, 1.14 Labels, signs and notices 1.14.2*.

20.12 Batteries

20.12.1 Batteries and battery installations are to be in accordance with the requirements of *Pt 16, Ch 2, 12 Batteries*.

20.13 Lightning conductors

20.13.1 Lightning conductors complying with IEC 60092-401: *Electrical installations in ships – Part 401: Installation and test of completed installation* are to be fitted to each mast of all wood, composite and steel craft having wooden masts or topmasts. They need not be fitted to steel craft having steel masts.

20.14 Fire detection and alarm systems

20.14.1 Where a fire detection and alarm system is fitted, it is to be in accordance with the requirements of *Pt 16, Ch 2, 17.1 Fire detection and fire alarm systems*.

20.15 Fire safety stops

20.15.1 Stops for ventilation fans for machinery spaces and enclosed galleys are to comply with the applicable paragraphs of *Pt 16, Ch 2, 17.6 Fire safety stops*.

20.16 Internal communication and alarm systems

20.16.1 Where internal communication and alarm systems are provided for use in an emergency, they are to comply with the requirements of *Pt 16, Ch 2, 18.2 General emergency alarm system* and *Pt 16, Ch 2, 18.3 Public address system* as appropriate.

■ *Section 21* Testing and trials

21.1 Testing

21.1.1 Tests in accordance with *Pt 16, Ch 2, 21.1 Testing 21.1.2* are to be satisfactorily carried out on all electrical equipment, complete or in sections, at the manufacturer's premises and a test report issued by the manufacturer.

21.1.2 A high voltage at any frequency between 25 and 100Hz is to be applied between:

(a) all current carrying parts connected together and earth;
(b) all current carrying parts of opposite polarity or phase.

For rotating machines the value of test voltage is to be 1000 V plus 2 x rated voltage with a minimum of 2000 V, and for other electrical equipment, it is to be in accordance with *Table 2.21.1 Test voltage*. Items of equipment included in the assembly for which a test voltage lower than the above is specified may be disconnected during the test and tested separately at the appropriate lower test voltage. The test is to be commenced at a voltage of about one-third the test voltage and is to be increased to full value as rapidly as is consistent with its value being indicated by the measuring instrument. The full test voltage is then to be maintained for one minute, and then reduced to one-third full value before switching off. The assembly is considered to have passed the test if no disruptive discharge occurs.

Table 2.21.1 Test voltage

Rated voltage, U_n U_n V	Test voltage a.c. (r.m.s.), V
$U_n \le 60$	500
$60 < U_n \le 1000$	$2 \times U_n + 1000$
$1000 < U_n \le 2500$	6500
$2500 < U_n \le 3500$	10000
$3500 < U_n \le 7200$	20000
$7200 < U_n \le 12000$	28000

21.1.3 When it is desired to make additional high voltage tests on equipment which has already passed its tests, the voltage of such additional tests is to be 80 per cent of the test voltage the equipment has already passed.

21.1.4 Immediately after the high voltage test, the insulation resistance is to be measured using a direct current insulation tester, between:

(a) all current carrying parts connected together and earth;
(b) all current carrying parts of different polarity or phase.

The minimum values of test voltage and insulation resistance are given in *Table 2.21.3 Test voltage and minimum insulation*.

21.1.5 Tests in accordance with the standard with which the equipment complies may be accepted as an alternative to the above.

21.1.6 Tests at the manufacturers' works and after installation on board are to include such tests necessary to demonstrate, to the Surveyor's satisfaction, the suitability and safety of the lithium battery system for its intended duty and location. As a minimum, the tests listed in *Table 2.21.2 Test requirements on lithium battery systems* are required.

Table 2.21.2 Test requirements on lithium battery systems

Item	Tests	Trials
Discharge performance validation	X	
Capacity validation test *	X	X
Internal d.c. resistance test	X	
Overcharge control test	X	
Cell balancing functional test	X	
Sensor failures test	X	
SOC validation test *	X	X
SOH validation test *	X	X
High voltage test	X	
Insulation resistance test	X	
Emergency trip functional test *	X	X
Over-temperature protection test	X	X
Over-voltage protection test	X	X
Under-voltage protection test	X	X
Communication failure between BMS and external charge control system test *	X	X
Pressure relief valve test	X	
Additional safety functions tests and trials of the battery management system	X	X
Note . Items marked * are required to be tested annually.		

21.2 Trials

21.2.1 Before a new installation, or any alteration or addition to an existing installation, is put into service the applicable trials in *Pt 16, Ch 2, 21.2 Trials 21.2.2* are to be carried out. These trials are in addition to any acceptance tests which may have been carried out at the manufacturer's works.

21.2.2 The insulation resistance is to be measured of all circuits and electrical equipment, using a direct current insulation tester, between:

(a) all current carrying parts connected together and earth; and so far as is reasonably practicable,
(b) all current carrying parts of different polarity or phase;

The minimum values of test voltage and insulation resistance are given in *Table 2.21.3 Test voltage and minimum insulation*. The installation may be subdivided and appliances may be disconnected if initial tests produce results less than these figures.

21.2.3 Tests are to be made to verify the effectiveness of:

(a) earth continuity conductor;

(b) the earthing of non-current carrying exposed metal parts of electrical equipment and cables not exempted by *Pt 16, Ch 2, 1.12 Earthing of non-current carrying parts 1.12.2* or *Pt 16, Ch 2, 20.7 Earthing 20.7.2*;

(c) bonding for the control of static electricity.

Table 2.21.3 Test voltage and minimum insulation

Rated voltage U_n V	Minimum voltage of the tests, V	Minimum insulation resistance, MΩ
$U_n \leq 250$	$2 \times U_n$	1
$250 < U_n \leq 1000$	500	1
$1000 < U_n \leq 7200$	1000	$\frac{U_n}{1000} + 1$
$7200 < U_n \leq 15000$	5000	$\frac{U_n}{1000} + 1$

21.2.4 It is to be demonstrated that the Rules have been complied with in respect of:

(a) satisfactory performance of each generator throughout a run at full rated load;

(b) temperature of joint, connections, circuit-breakers and fuses;

(c) the operation of engine governors, synchronising devices, overspeed trips, reverse-current, reverse-power and over-current trips and other safety devices;

(d) voltage regulation of every generator when full rated load is suddenly thrown off and when starting the largest motor connected to the system;

(e) voltage drop at the worst case condition;

(f) harmonic distortion of the voltage waveform. Where harmonic filters are installed the calculation results provided by the system integrator are to be verified by the Surveyor. Simulation of harmonic filter failure during trials is not to exceed the THD limit. *See Pt 16, Ch 2, 5.11 Harmonic filtering*;

(g) satisfactory parallel operation, and kW and KVA load sharing of all generators capable of being operated in parallel at all loads up to normal working load;

(h) alarm sound pressure levels; and

(i) all essential and other important equipment are to be operated under service conditions, though not necessarily at full load or simultaneously, for a sufficient length of time to demonstrate that they are satisfactory.

21.2.5 Measurements are to be taken as part of the trials specified in *Pt 16, Ch 2, 21.2 Trials 21.2.4.(c)*, *Pt 16, Ch 2, 21.2 Trials 21.2.4.(d)*, *Pt 16, Ch 2, 21.2 Trials 21.2.4.(e)* and *Pt 16, Ch 2, 21.2 Trials 21.2.4.(f)* to verify that the installation will provide a quality of power supply in accordance with the values listed in *Pt 16, Ch 2, 1.8 Quality of power supplies*.

21.2.6 It is to be demonstrated by practical tests that the Rules have been complied with in respect of fire, crew and passenger emergency and craft safety systems.

21.2.7 On completion of the general emergency alarm system and public address system tests, the Surveyor is to be provided with two copies of the test schedule, detailing the measured sound pressure levels. Such schedules are to be signed by the Surveyor and the Builder.

■ *Section 22*
Ergonomic Lighting Design – ELD optional notation

22.1 Objectives

22.1.1 The requirements in this Section are applicable where the optional class notation for ergonomic lighting design is requested.

22.1.2 The design and installation of indoor lighting is to facilitate visual task performance, safety and visual comfort. In order to achieve this goal the requirements of *Pt 16, Ch 2, 22.2 Positioning and installation* are to be complied with.

22.1.3 The requirements in this Section do not address emergency or navigational lighting.

22.2 Positioning and installation

22.2.1 In order to meet the ergonomic requirements of *Pt 16, Ch 2, 22.3 Luminance distribution* the positioning and installation of lights is to comply with *Pt 16, Ch 2, 22.2 Positioning and installation 22.2.2*

22.2.2 Natural lighting through the use of windows and doors is to be provided as far as practicable.

22.2.3 Lights are to be positioned, as far as practicable, in the same horizontal plane and arranged symmetrically to produce a uniform level of illumination.

22.2.4 Lights are to be positioned so as to reduce bright spots and shadows as far as possible.

22.2.5 Lights are to be positioned taking account of structures such as beams and columns etc. so the lighting is not blocked by these items.

22.2.6 Lights are not to be positioned in locations which would result in limited illumination.

22.2.7 Lights are to be positioned taking account of air-conditioning vents or fans, fire detectors, water sprinklers etc. so the lighting is not blocked by these items.

22.2.8 The position of lights configured to strips or tubes is, as far as practicable, to be at right angles to an operator’s line of sight while the operator is located at their typical duty station.

22.2.9 Any physical hazards that provide a risk to operator safety are to be appropriately illuminated.

22.2.10 The positioning of lights is to consider the transfer of heat to adjacent surfaces.

22.2.11 Lights are to be positioned in locations that are easy to reach for lamp replacement or maintenance.

22.3 Luminance distribution

22.3.1 In order to provide even, fatigue-free illumination the requirements of *Pt 16, Ch 2, 22.3 Luminance distribution 22.3.2* are to be complied with.

22.3.2 The light levels falling on the plane in which a task is performed are to be suitable for the type of task, i.e. they are to consider the variation in the working planes.

22.3.3 Sharp contrasts in illumination levels across an operator task or working plane are to be avoided, as far as possible.

22.3.4 Sharp contrasts in illumination levels between an operator task area and the immediate surround and general background area are to be avoided, as far as possible.

22.3.5 Where required, local lighting for operational tasks is to be provided in addition to general lighting.

22.3.6 Lighting is to be free of perceived flicker.

22.4 Glare

22.4.1 In order to minimise glare (to avoid dazzle, discomfort and fatigue) the requirements of *Pt 16, Ch 2, 22.4 Glare 22.4.2* are to be complied with.

22.4.2 Lights are to be positioned so as to reduce, as far as possible, glare or high brightness reflections from working and display surfaces.

22.4.3 Lights are to be positioned so as to provide even illumination and minimal glare on controls, displays and indicators.

22.4.4 Where necessary, suitable blinds and shading devices are to be used to prevent glare.

22.4.5 Surfaces are to have a non-reflective or matt finish in order to reduce the likelihood of indirect glare.

22.4.6 Where a transparent cover is fitted over a control, display or indicator, it is to be designed to minimise reflections.

22.5 Location of lighting controls and outlets

22.5.1 In order to allow convenient use of lighting the requirements of *Pt 16, Ch 2, 22.5 Location of lighting controls and outlets 22.5.2* are to be complied with.

22.5.2 The lighting system is to be easily maintained and operated by personnel.

22.5.3 Lighting is to be controllable locally in accommodation and working areas, except where this conflicts with safety requirements.

22.5.4 Light switches are to be fitted in safe positions for personnel.

22.5.5 The mounting height of switches is to be such that personnel can reach switches with ease.

22.5.6 Power outlets are to be provided where temporary, local, task lighting will be required, except in hazardous areas.

22.6 Night vision

22.6.1 In order to maintain night vision and facilitate safety during hours of darkness the requirements of *Pt 16, Ch 2, 22.6 Night vision 22.6.2* are to be complied with.

22.6.2 Lighting on the ship's superstructure is to be directed away from, and shaded to prevent direct illumination of, the bridge windows and lookout points.

22.6.3 Instrument lighting is to be such that the operator can read dials and indicators without impediment of night vision.

22.6.4 Lighting of instruments, keyboards and controls, is to be adjustable down to zero, except for the lighting of alarm and warning indicators and the controls of dimmers, which are to remain readable.

■ *Section 23*
Hybrid electrical power systems

23.1 Scope

23.1.1 The requirements of this Section are applicable to ships having a main source of electrical power which is provided by hybrid electrical power generation and distribution systems within which the main electrical power demand is supplied by two or more different types of power source or by stored electrical energy.

23.1.2 These requirements apply to the design, construction and integration of hybrid electrical power systems, their sub-systems, machinery and equipment.

23.1.3 These requirements apply to hybrid electrical power systems which provide the main source of electrical power and exceptionally, where permitted by the National Administration, the emergency source of electrical power.

23.1.4 In addition to these requirements National Administrations may impose further requirements. Where such requirements conflict with these requirements, the requirements of the National Administration will take precedence.

23.1.5 These requirements are additional to the applicable requirements of the *Rules and Regulations for the Classification of Special Service Craft, July 2021*.

23.2 Characters of classification and class notations (machinery special features)

23.2.1 Ships complying with the mandatory requirements of this Section will be assigned the **Hybrid Power** machinery special features notation.

23.2.2 Ships complying with both the mandatory requirements and the additional optional requirements of this Section will be assigned the **Hybrid Power (+)** machinery special features notation.

23.2.3 **Hybrid Power**: Assigned to ships with an electrical power system including a combination of two or more different types of power source or utilising stored electrical energy to satisfy the ship's main power demand. The system and its component parts are in accordance with the existing applicable requirements of the Rules and the requirements of *Pt 16, Ch 2, 23 Hybrid electrical power systems*.

23.2.4 **Hybrid Power (+)**: Assigned to ships meeting the requirements for **Hybrid Power** and the additional optional requirements for **Hybrid Power (+)** specified within *Pt 16, Ch 2, 23 Hybrid electrical power systems*. The additional optional requirements aim to provide for enhanced performance of the electrical power system achieved through the consideration of system simulation, system integration and the dependability of the electrical power system during normal or reasonably foreseeable abnormal operation.

23.3 Definitions

23.3.1 Hybrid electrical power system: A ship's electrical power system comprising sources, stores, consumers and distribution of electrical power together with their associated controls within which electrical power is provided by two or more different types of power source or utilising stored electrical energy to satisfy the ship's main power demand. This definition is independent of:

(a) the type of distribution system (*see Pt 16, Ch 2, 23.3 Definitions 23.3.7*);
(b) the types and ratings of source, their physical location and time duration of connection to the ship's power system;
(c) the types of store;
(d) the types of connected consumer; and
(e) the presence or otherwise of electric propulsion.

23.3.2 Reasonably foreseeable abnormal condition: A reasonably foreseeable abnormal condition is an operation, event, incident or failure that:

(a) has happened and could happen again;
(b) has not happened but is considered possible. Where the likelihood is considered extremely unlikely or the consequences are trivial, and no further prevention or mitigation action is to be taken, then this is to be justified; and
(c) is planned for (e.g. emergency actions cover such a situation, maintenance is undertaken to prevent it, etc.).

They should be identified by:

(a) using analysis processes that are capable of revealing abnormal conditions;
(b) employing a mix of personnel including designers, Operators, persons who carry out maintenance and competent safety/risk professionals with relevant domain knowledge and understanding to apply the processes;
(c) referencing relevant events and historic data; and
(d) documenting the results of the analysis.

23.3.3 Source of electrical power: A source of electrical power produces electrical power from an energy source such that its output may be connected to ship's electrical power distribution system (*see Figure 2.23.1 Source of electrical power*). It includes:

(a) Dedicated conversion where conversion is the changing of an output with respect to its input and may include change of form (e.g. a.c. to d.c. or d.c. to a.c.), change in magnitude (e.g. of voltage, current or frequency), change in phase or change in reference (e.g. through galvanic isolation);
(b) Management systems perform monitoring, control, protection and safety functions that are likely to be connected to higher level ship wide supervisory systems; and
(c) Systems providing control, alarm, monitoring and safety functions such as control panel, governor, automatic voltage regulator (AVR) and emergency shutdown (ESD) system for a reciprocating engine or gas turbine generator.

This definition of source of electrical power is independent of:

(a) the type of source (e.g. rotating generator, waste heat recovery system, wind generator, solar panel, fuel cell, photovoltaic array);
(b) the type of distribution system (*see Pt 16, Ch 2, 23.3 Definitions 23.3.7*); and
(c) the application of the source (e.g. main/additional/emergency/transitional source of power).

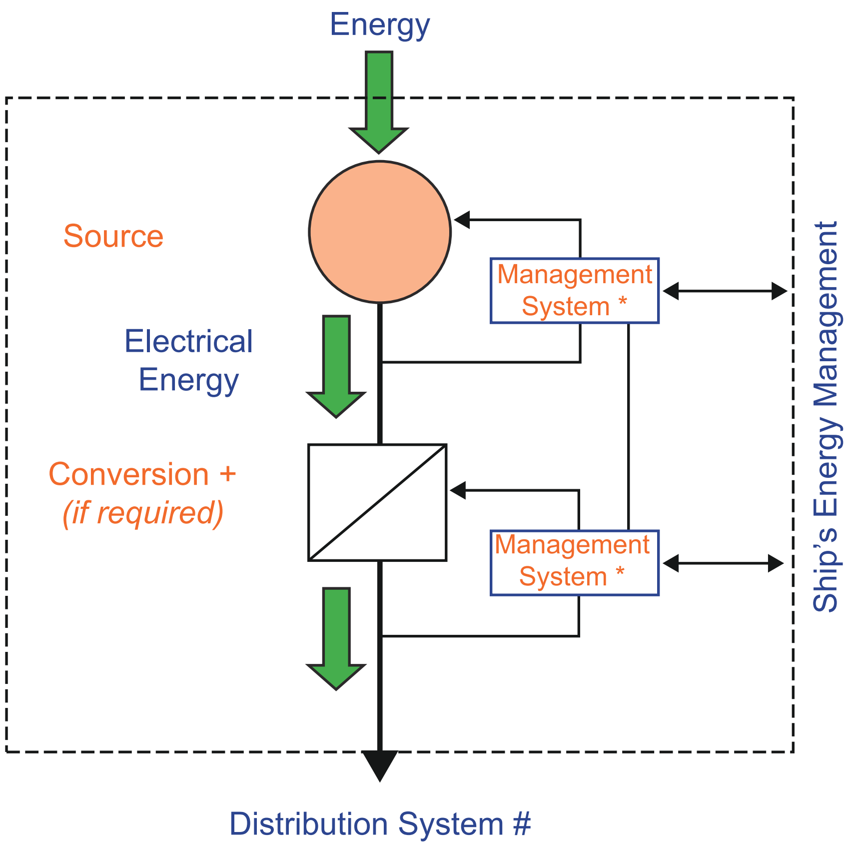


Figure 2.23.1 Source of electrical power

23.3.4 Additional source of electrical power: An additional source of power is a source of electrical power not forming part of the ship's main source of power that is rated to supply any proportion of the ship's main power demand at any time either continuously or for an accepted period of time, e.g. an energy storage device or a power take-off that is not rated for or capable of permanent operation.

23.3.5 Store of electrical energy: A store of electrical energy receives, stores and discharges energy through a single point of common coupling with the distribution system (*see Figure 2.23.2 Store of electrical energy*). It includes management systems and any required dedicated conversion as defined in *Pt 16, Ch 2, 23.3 Definitions 23.3.4*. This definition is independent of:

(a) the method of energy storage;

(b) the type of store (e.g. battery, capacitor);

(c) the type of distribution system (*see Pt 16, Ch 2, 23.3 Definitions 23.3.7*); and

(d) the application of the store (e.g. power source, load smoothing, peak shaving, dynamic response, power backup).

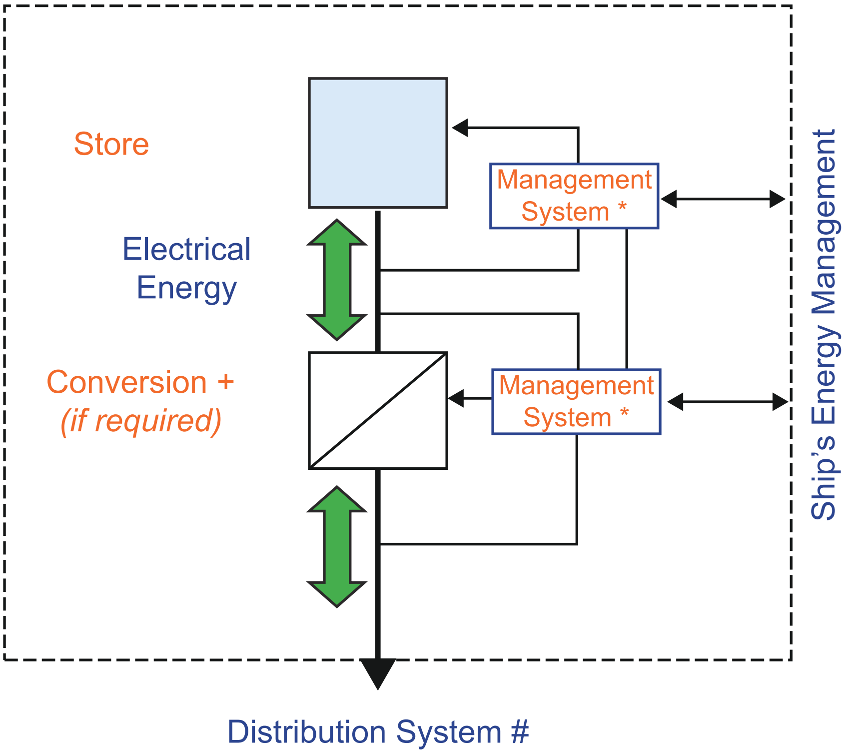


Figure 2.23.2 Store of electrical energy

23.3.6 Consumer of electrical power: A consumer of electrical power takes its input from the electrical distribution system and delivers useful work through its associated load (*see Figure 2.23.3 Consumer of electrical power*). It includes management systems and any required dedicated conversion as defined in *Pt 16, Ch 2, 23.3 Definitions 23.3.3*. Consumers are present in any electrical power system and are not unique to hybrid electrical power systems. The definition is provided here for completeness. This definition is independent of:

(a) the type of load or the purpose for which it is installed; and

(b) the type or physical form of distribution system.

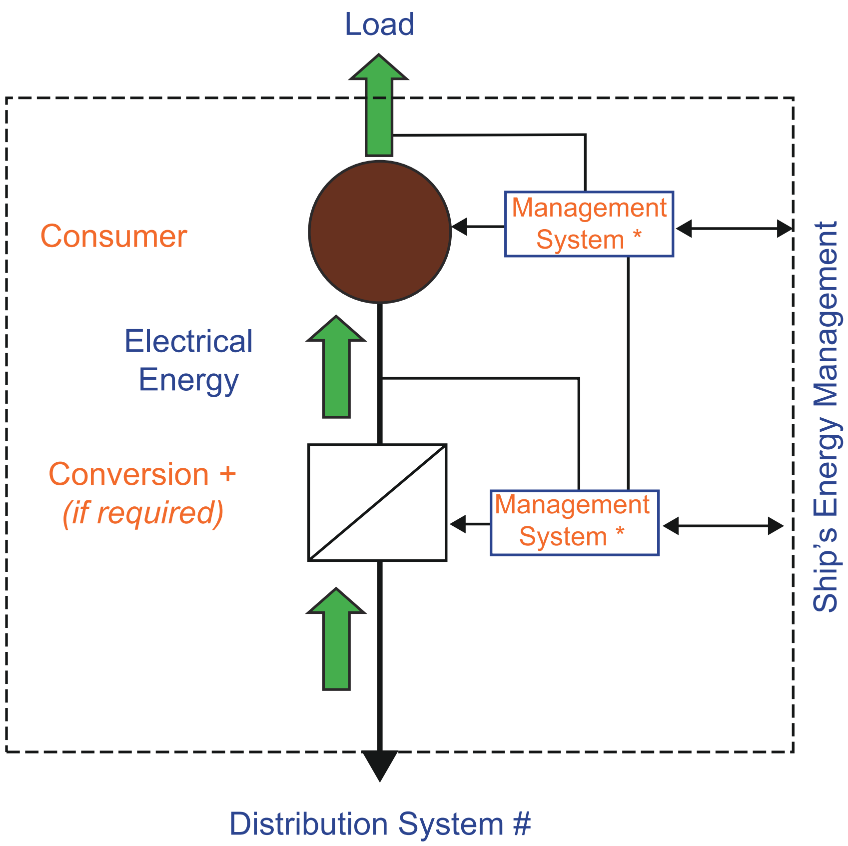


Figure 2.23.3 Consumer of electrical power

23.3.7 Combined sources/stores/consumers of electrical power: A combined source/store/consumer of electrical power provides multiple functions as defined in *Pt 16, Ch 2, 23.3 Definitions 23.3.4* to *Pt 16, Ch 2, 23.3 Definitions 23.3.6* in a single functional arrangement (some examples are shown in *Figure 2.23.4 Combined source and consumer of electrical power* to *Figure 2.23.7 Combined store of electrical energy and source and consumer of electrical power*). They include management systems and any required dedicated conversion as defined in *Pt 16, Ch 2, 23.3 Definitions 23.3.3*.

Figure 2.23.4 Combined source and consumer of electrical power to *Figure 2.23.7 Combined store of electrical energy and source and consumer of electrical power* depict building blocks that may be encountered in a hybrid electrical power system. These do not represent complete systems, are provided for illustration purposes only and are not exhaustive with further permutations being viable.

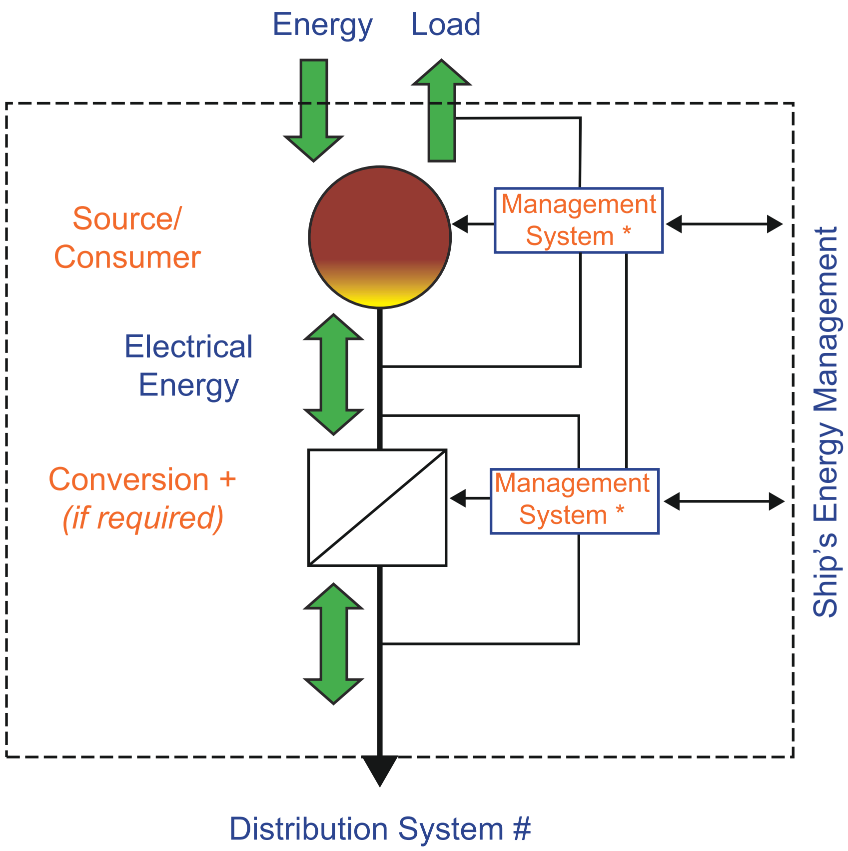


Figure 2.23.4 Combined source and consumer of electrical power

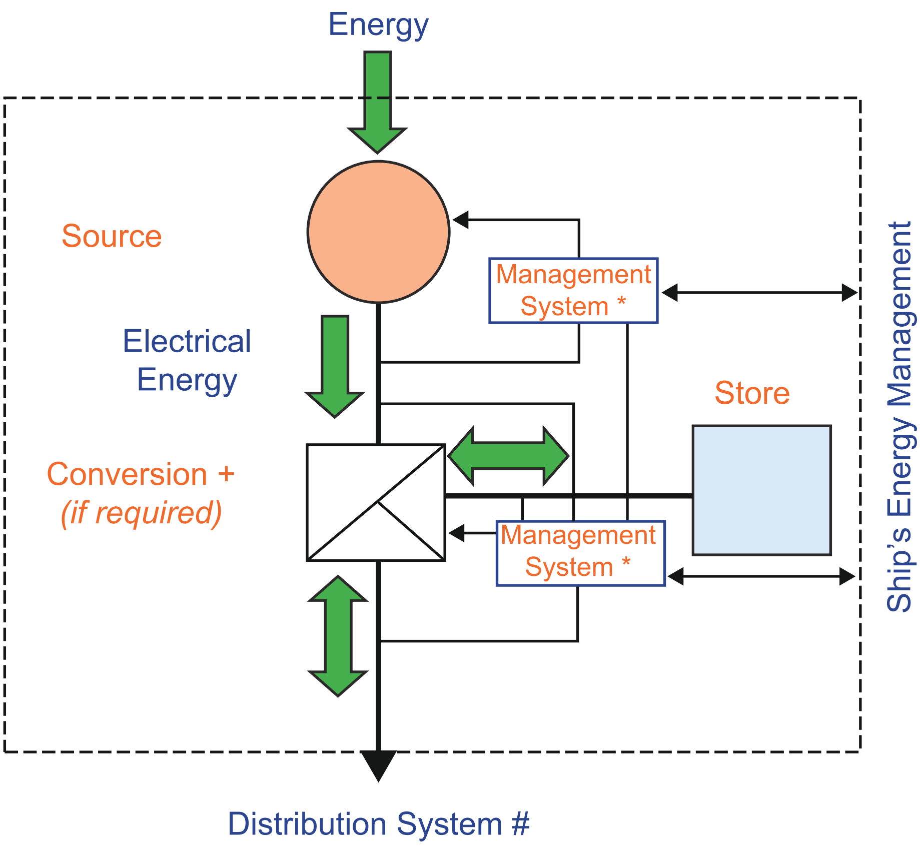


Figure 2.23.5 Combined source of electrical power and store of electrical energy

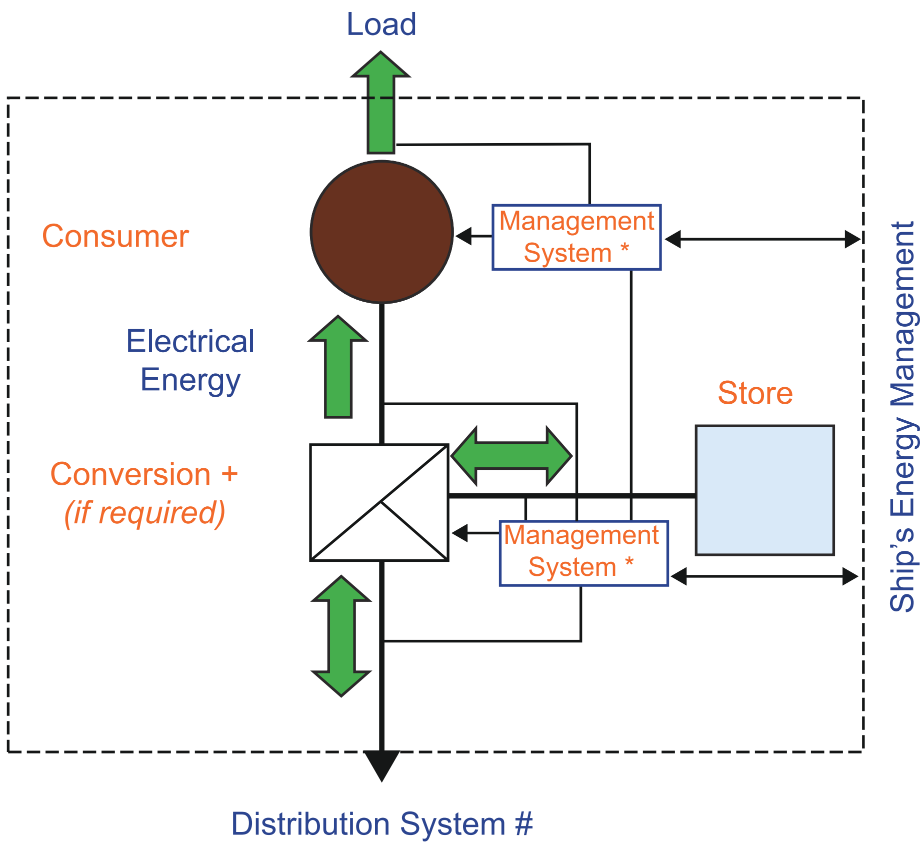


Figure 2.23.6 Combined store of electrical energy and consumer of electrical power

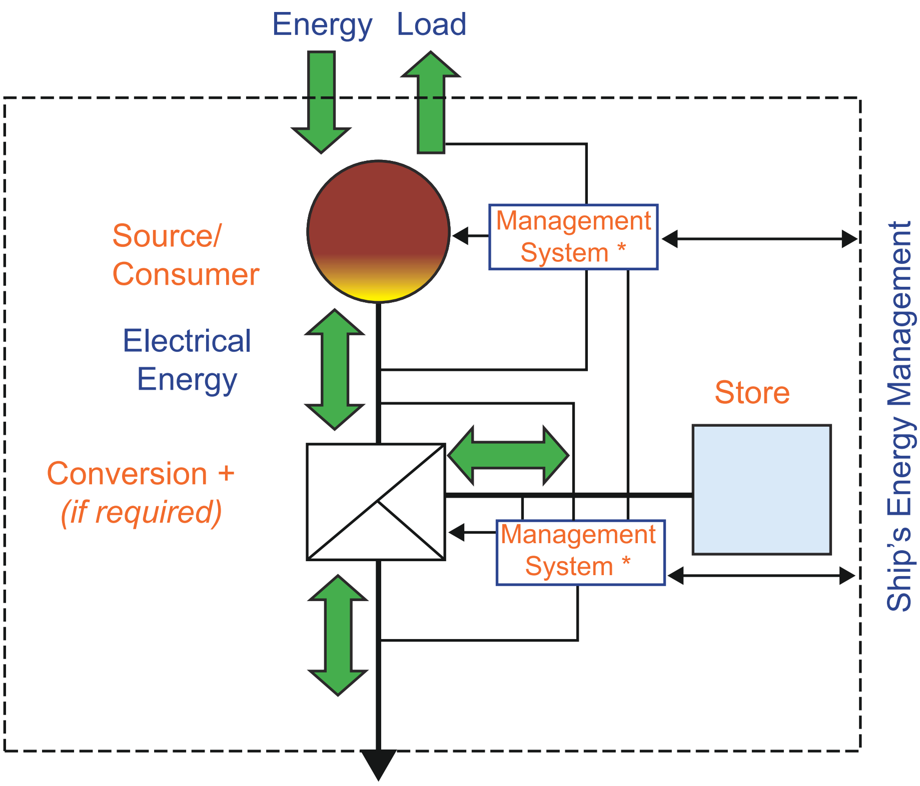


Figure 2.23.7 Combined store of electrical energy and source and consumer of electrical power

23.3.8 Distribution system: The distribution system provides the interconnection between, protection of and isolation of:

- sources (*see Pt 16, Ch 2, 23.3 Definitions 23.3.3* to *Pt 16, Ch 2, 23.3 Definitions 23.3.4*),
- stores (*see Pt 16, Ch 2, 23.3 Definitions 23.3.4*),
- consumers (*see Pt 16, Ch 2, 23.3 Definitions 23.3.5*) and
- combinations thereof (*see Pt 16, Ch 2, 23.3 Definitions 23.3.6*).

It includes management systems (e.g. power management) and any required dedicated conversion as described in *Pt 16, Ch 2, 23.3 Definitions 23.3.4*. There are no constraints on its type (e.g. a.c. or d.c.), magnitude (e.g. voltage and/or frequency), nature (e.g. fixed or variable), architecture (e.g. tree, radial, zonal), physical form or on the number of variants within a ship.

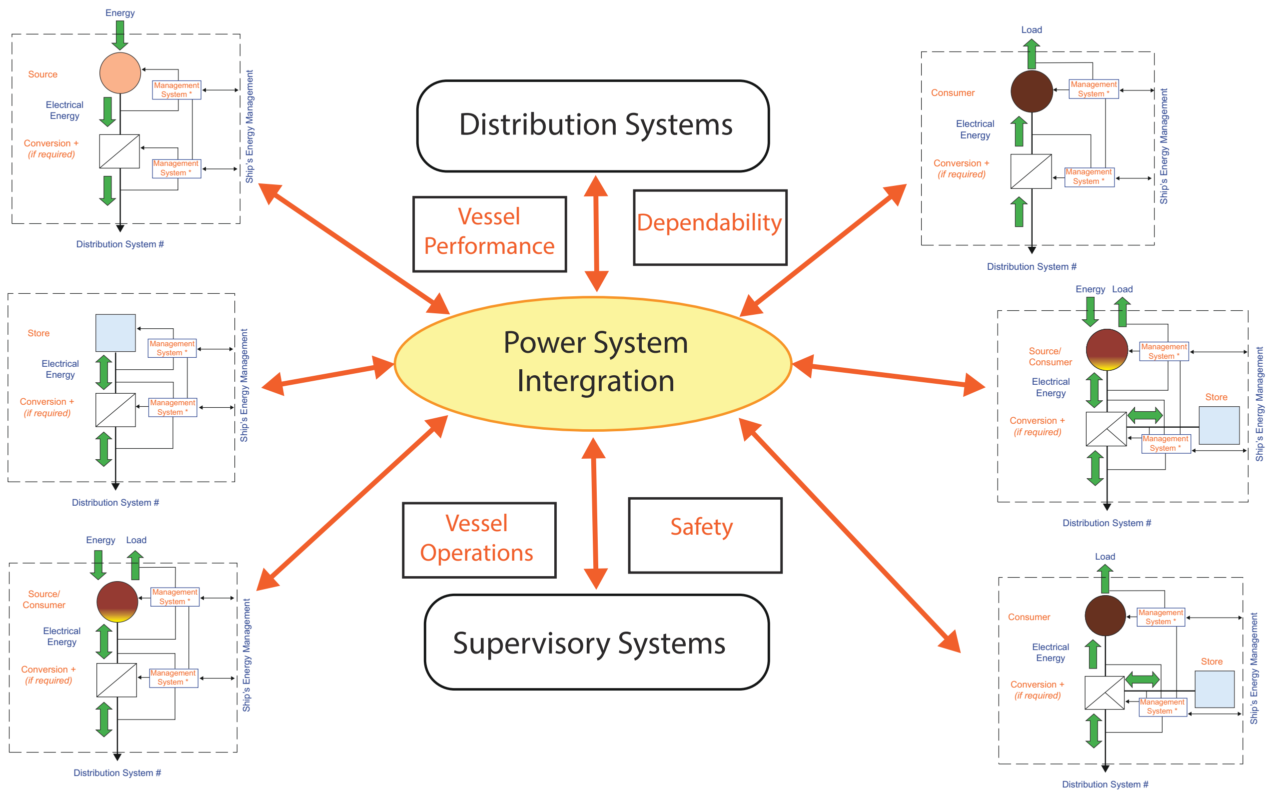
23.3.9 Energy management: Energy management functionality provides the overall control, monitoring, protection and safety functions that are necessary to deliver dependable electrical power from the hybrid electrical power system in all operating modes and under both normal and reasonably foreseeable abnormal conditions. It comprises supervisory functions that integrate the management systems of the components (sources, stores, consumers, distribution systems) from which the hybrid system is constructed and may be implemented as a stand-alone system or as distributed functionality across a number of systems.

Energy management is focused on energy flow and is typically model based, predictive in nature, inclusive of optimisation functionality and employing the principles of health and condition monitoring at system level (e.g. as described in *ShipRight Procedure for the Approval of Digital Health Management Systems*).

Energy management functionality is considered additional to the functionality of a conventional power management system as described in IEC 60092-504, *Electrical installations in ships, Part 504: Automation, control and instrumentation, section 9.4.*

23.3.10 Power system integration: Power system integration comprises those system level activities that are required to be undertaken to design and develop, build and then operate and maintain safely through life a dependable ship's hybrid electrical power system including its constituent components (shown pictorially in *Figure 2.23.8 Role of system integration activities*). At

each phase of a project power system integration is managed by a single designated party and is carried out in accordance with a defined procedure identifying the roles, responsibilities and requirements for all parties involved.



* "Supervisory Systems" may Include Intergrated Automation Systems (IAS), Power/Energy Management Systems (PMS/EMS), Dynamic Positioning (DP) Control Systens, Health/Condition Monitoring Systems..... etc.

Figure 2.23.8 Role of system integration activities

23.3.11 Dependability: Dependability is as defined in IEC 60050(191), *Quality vocabulary – Part 3: Availability, reliability and maintainability terms – Section 3.2: Glossary of international terms*. It is the collective term used to describe the availability performance and its influencing factors: reliability performance, maintainability performance and maintenance support performance as agreed with LR

23.4 Hybrid electrical power system performance - System functional requirements

23.4.1 To provide sufficient electrical power of appropriate dependability to supply the required essential services, habitability requirements and those services required to maintain the ship in a normal sea-going and operational state during defined operational conditions without recourse to the emergency electrical supply.

23.4.2 Damage and injury: To provide electrical systems and equipment with suitable protection under fault conditions to prevent the following:

(a) injury to onboard personnel;
(b) damage to the equipment itself; and
(c) damage to equipment connected to it.

23.4.3 On ships with electric propulsion, to provide sufficient electrical power necessary for an effective and agreed level of propulsion power during all normal and reasonably foreseeable abnormal operational conditions.

23.5 Hybrid electrical power system performance - System performance targets

23.5.1 For **Hybrid Power** notation the performance of the system is to be such that in the event of a single failure operation of the system may be interrupted but is to be recoverable to a defined state bounded by time and magnitude.

23.5.2 For **Hybrid Power (+)** notation the performance of the system is to be such that in the event of a single failure operation of the system is to be uninterrupted with any degradation of performance agreed between the designers and Owners.

23.5.3 The hybrid electrical power system performance targets in all modes of operation are to be defined and agreed between the designers and Owners.

23.5.4 The electrical system design maximum and minimum operating voltage and input frequency together with acceptable limits of excursions are to be specified by the system designer and are to be in compliance with the requirements of the Rules.

23.5.5 Specific consideration is to be given to time-based performance targets for systems in which stored electrical energy supplies any part of the ship's main power demand.

23.5.6 Methods of verification of actual performance against targets are to be defined and are to cover all phases of the lifecycle.

23.6 Hybrid electrical power system performance - Dependability principles

23.6.1 The hybrid electrical power system dependability principles are to be defined and agreed between the designers and Owners consistent with the requirements for **Hybrid Power** or **Hybrid Power (+)** notation.

23.6.2 The principles are to cover defined operating modes, all normal and reasonably foreseeable abnormal operating and fault conditions and are to specifically consider the fault ride-through capability of the system.

23.6.3 The principles are to cover failures in active components of any of the sources, stores, consumers, distribution system and energy management forming the hybrid electrical power system. Such components may include, but are not restricted to, the following:

(a) Prime movers (e.g. auxiliary engines);
(b) Generators and their excitation equipment;
(c) Gearing;
(d) Pumps;
(e) Fans;
(f) Switchgear and controlgear, including their assemblies;
(g) Thrusters; and
(h) Valves (where power actuated).

23.6.4 Consideration is to be given to other enabling systems not part of the hybrid electrical power system whose failure or degradation could affect correct functioning of the hybrid electrical power system (e.g. lubrication, cooling and ventilation systems).

23.6.5 The continuity of supply to essential and emergency safety systems is to be maintained, in accordance with *Pt 16, Ch 2, 2 Main source of electrical power*.

23.6.6 Arrangements are to ensure that the supply of essential services is not disrupted by the unavailability of the largest source of electrical power and are to be in accordance with a clearly described, documented and agreed redundancy design intent.

23.6.7 The size and rating of electrical energy stores is to be appropriate for the specified lifetime when subjected to in-service cyclic loading. Calculations supporting this assessment are to be provided to LR.

23.6.8 For **Hybrid Power (+)** notation, a hybrid electrical power system dependability assessment is to be undertaken and submitted to LR. The objectives of the assessment are to:

(a) demonstrate the dependability of the system during all normal and reasonably foreseeable abnormal conditions; and
(b) demonstrate that an appropriate level of dependability is achieved that is commensurate with that agreed between the designers and Owners.

The assessment shall be undertaken to a recognised standard that is acceptable to LR (e.g. IEC 60300-3-1, *Dependability management Part 3-1: Application guide – Analysis techniques for dependability – Guide on methodology*).

23.7 Hybrid electrical power system performance - Main source of electrical power

23.7.1 The main source of electrical power is to comply with the requirements of *Pt 16, Ch 2, 2 Main source of electrical power*.

23.7.2 Any type of source of electrical power as detailed in these hybrid electrical power system Rules may, subject to the approval of LR, be considered as having equivalent function of that of a generating set as described in the SSC Rules including, but not limited to, *Pt 16, Ch 2, 2 Main source of electrical power*.

23.7.3 Sources of electrical power not forming part of the ship's main source of electrical power may be used as an additional source of electrical power to supply electrical services required for normal operational and habitable conditions provided that:

(a) The quality of power supplies meets the requirements of *Pt 16, Ch 2, 23.17 Transversal requirements 23.17.3*; and
(b) Automatic arrangements are provided to start and connect within a period not exceeding 45 seconds one of the sources forming the main source of electrical power in the event of a single failure or the quality of power supplies exceeding limits.

23.8 Hybrid electrical power system performance - Emergency source of electrical power

23.8.1 The emergency source of electrical power is to comply with the requirements of *Pt 16, Ch 2, 3 Emergency source of electrical power*.

23.8.2 For ships with a specified service notation as defined in *Pt 1, Ch 2, 3.3 Class notations (hull)*, where it is proposed that a dedicated emergency source of electrical power and its associated transitional source of power will not be provided, the main source of electrical power and associated equipment is to meet the following requirements:

(a) Sources providing the main source of electrical power are to be:
    (i) separated and located in two or more compartments that are not contiguous with each other;
    (ii) self-contained and arranged to be independent such that each system can operate without recourse to the other main source(s) including power distribution and any associated auxiliary and ancillary converting equipment and control systems;
    (iii) arranged such that a fire, flood or casualty in any one of the compartments will not affect the electrical power distribution from the other(s), or to the services required by *Pt 16, Ch 2, 3 Emergency source of electrical power*;
    (iv) capable of being started automatically on loss of the power supplied by the other main source(s) of electrical power and supplying the essential services as quickly as is safe and practicable subject to a maximum of 45 seconds, or provided with a transitional source of emergency electrical power;
    (v) arranged to allow for maintenance at sea of any one source without affecting the ability to comply with these requirements; and
    (vi) provided with starting arrangements compliant with the requirements of *Pt 10, Ch 1, 9.5 Starting of the emergency source of power*.
(b) Where these Rules specify that a service is required to be connected to both the main and emergency source of electrical power or is to be connected to the emergency switchboard, then these services are to be served by at least two individual circuits from the separated main sources of electrical power with arrangements to transfer between the two sources. The supplies are to be separated in their switchboard and throughout their length as widely as is practicable without the use of common feeders, protective devices, control circuits or controlgear assemblies so that any single fault will not cause the loss of both supplies.
(c) Provision is to be made for periodic testing to demonstrate services required by *Pt 16, Ch 2, 3 Emergency source of electrical power* can be supplied automatically following the loss of one main source of electrical power.
(d) To demonstrate compliance with these requirements a risk assessment of the electrical, mechanical, piping arrangements, cooling arrangements and any other sub-systems whose failure or degradation could have an impact on the performance of the system is to be carried out demonstrating that a single point failure such as a fire or flooding within a space would not render the systems incapable of supplying those services required in an emergency or other reasonably foreseeable abnormal event. The assessment is to be undertaken to a recognised standard that is acceptable to LR (e.g. ISO 31010, *Risk management – Risk assessment techniques*) and in accordance with *ShipRight Procedure Assessment of Risk Based Designs* and associated annexes.

23.9 Hybrid electrical power system performance - External source of electrical power

23.9.1 Ships utilising an external source of power are to comply with the requirements of *Pt 16, Ch 2, 4 External source of electrical power*.

23.9.2 Arrangements for d.c. external sources are to comply with a recognised standard that is acceptable to LR.

23.9.3 An external source of power may be used to charge onboard stores of electrical energy. Details of any such arrangements and their interfaces to ship systems are to be provided for consideration by LR.

23.10 Hybrid electrical power system performance – Electrical power supply to ship propulsion and ship positioning systems

23.10.1 Ships with electric propulsion are to comply with the relevant power requirements of *Pt 16, Ch 2, 16.1 General*.

23.10.2 Ships with electrically driven azimuthing thrusters are to comply with the relevant power requirements *Pt 12, Ch 3, 7.2 Emergency power for steering systems and drives 7.2.1*.

23.11 Hybrid electrical power system components - Source of electrical power

23.11.1 The main source of electrical power is to comply with the requirements of *Pt 16, Ch 2, 2 Main source of electrical power*.

23.11.2 The emergency source of electrical power is to comply with the requirements of *Pt 16, Ch 2, 3 Emergency source of electrical power*.

23.11.3 External sources of electrical power are to comply with the requirements of *Pt 16, Ch 2, 4 External source of electrical power*.

23.11.4 Additional sources of electrical power as defined in *Pt 16, Ch 2, 23.3 Definitions 23.3.4* are to comply with the requirements of this Chapter.

23.11.5 Rotating electrical generators within sources of electrical power are to comply with the requirements of *Pt 16, Ch 2, 9 Rotating machines*.

23.11.6 Converters within power sources are to comply with *Pt 16, Ch 2, 10.2 Semiconductor converters* and the following requirements:

(a) Converters are to be selected to withstand the voltage ripple levels present on the distribution system. For every system, the following voltage parameters are to be defined:
  (i) maximum non-repetitive peak;
  (ii) maximum repetitive peak; and
  (iii) maximum repetitive peak-to-peak.
(b) Where pulse width modulation converters are to be used, the voltage rate of rise times are to be determined, the results recorded and submitted to LR. Rotating machinery, surge protective devices, cable insulation and motor windings are to be designed accordingly.
(c) Converters may be of conversion type a.c./a.c., d.c./a.c., a.c./d.c., d.c./d.c., and can be of the controlled (e.g. active front end (AFE)) or non-controlled type (e.g. diode supply unit (DSU)).
(d) Converters are to be provided with visual status indication at their associated control stations to include, but not be limited to:
  (i) Power available at the input;
  (ii) Power at output;
  (iii) Temperature; and
  (iv) Overload.

  If certain indicators and alerts are not applicable, sufficient evidence to support the claim is to be submitted for consideration by LR . Additional indicators, alerts and shutdowns may be necessary as determined through the system Failure Modes and Effects Analysis (FMEA) required by *Pt 16, Ch 2, 23.27 Power system development and integration - System Failure Modes and Effects Analysis (FMEA)*.
(e) Converters supplying electrical power to the distribution system and consumers are to be capable of delivering the required currents for the time required to enable current-time discrimination of protective devices to operate. The electrical output of the converter is to be automatically restored following fault clearance.
(f) Converter software is to satisfy the requirements of *Pt 16, Ch 1, 2 Essential features for control, alarm, monitoring and safety systems*.
(g) Converters are to be capable of handling voltage and current spikes from the distribution system under all normal and reasonably foreseeable abnormal conditions without sustaining any damage or tripping.

(h) Converters supplying essential services are to automatically restart and connect to the distribution system after a blackout as specified in *Pt 16, Ch 2, 2.2 Number and rating of generators and converting equipment*.

(i) Where converters are equipped with internal capacitors which can contribute significantly to the short-circuit level of the system, the contribution is to be included in the design of the protection and distribution system.

(j) The risk of converter component damage due to inrush currents is to be minimised by appropriate management of these currents during transient events and after short circuit.

(k) Where capacitors are connected to a converter output, the output is to be charged by the converter or by external chargers to a level which will minimise the risk of damage to the capacitors before connecting them to the distribution system.

(l) Converters arranged to operate in parallel are to be capable of stable load sharing up to maximum continuous load and inclusive of any temporary overloads within their design rating.

(m) Where converters are arranged to provide protection against electrical faults a disconnector or switch disconnector is to be provided to enable safe isolation of the converter from its incoming supplies.

(n) Converters are to be protected from permanent physical damage as a result of short circuits or overload currents on their input and output terminals.

(o) Converters are to have a ride-through capability to manage system transients including the effects of fault clearance in the distribution system that is consistent with the dependability requirements of the system.

(p) Converters are to be provided with appropriate filters to ensure the required quality of power supply at both their input and output. In the event of filter circuit failure, continued safe operation of the hybrid electrical power system is to be possible by following specified procedures as described in operation procedures. These procedures are to include any operational limitations, and they are to be kept on board, maintained in accordance with *Pt 16, Ch 2, 23.18 Power system development and integration - General* and made available to the Surveyor on request.

23.12 Hybrid electrical power system components - Store of electrical energy

23.12.1 Functional requirements: To provide sufficient stored electrical energy as a component of the main source of power to supply services during normal and reasonably foreseeable abnormal and emergency conditions.

23.12.2 Batteries of the vented and valve-regulated sealed type and lithium batteries are to comply with *Pt 16, Ch 2, 12 Batteries*.

23.12.3 Power converters within stores of electrical energy as illustrated in *Pt 16, Ch 2, 23.3 Definitions 23.3.4* are to comply with the relevant requirements of *Pt 16, Ch 2, 23.11 Hybrid electrical power system components - Source of electrical power 23.11.6*.

23.12.4 For consideration as a component of the main source of power on a ship with a specified service notation as defined in *Pt 1, Ch 2, 3.3 Class notations (hull)* and subject to approval of the National Administration a store of electrical energy is to:

(a) Comply with *Pt 16, Ch 2, 23.7 Hybrid electrical power system performance - Main source of electrical power*;

(b) Have a minimum capacity at any stage of its lifecycle sufficient for its contribution to the main source of power that is necessary to achieve the specified service requirements;

(c) Be provided via energy management functionality with remote indication of state of charge (available capacity in a store expressed as a percentage of rated capacity) and state of health (general condition of a store expressed as a percentage of its ability to deliver the specified performance compared with that of a new store);

(d) Have a primary purpose of supplying the ship's main power demand. Details of any secondary purpose including but not limited to optimising performance (e.g. load smoothing, peak shaving), improving stability (e.g. dynamic response) or providing transitional power are to be provided to LR; and

(e) Be capable of being restored from a dead-ship condition with no dependence on other systems or electrical supplies. Details of alternative arrangements may be submitted for consideration by LR.

23.12.5 For consideration as an additional source of power a store of electrical energy is to:

(a) Comply with *Pt 16, Ch 2, 23.7 Hybrid electrical power system performance - Main source of electrical power 23.7.3*;

(b) Be provided via energy management functionality with remote indication of State of Charge (available capacity in a store expressed as a percentage of rated capacity) and State of Health (general condition of a store expressed as a percentage of its ability to deliver the specified performance compared with that of a new store); and

(c) Have a primary purpose of supplying the ship's main power demand. Details of any secondary purpose including but not limited to optimising performance (e.g. load smoothing, peak shaving), improving stability (e.g. dynamic response) or providing transitional power are to be provided to LR.

23.12.6 For application as an emergency source of power a store of electrical energy is to comply with *Pt 16, Ch 2, 23.8 Hybrid electrical power system performance - Emergency source of electrical power*.

23.12.7 Electrical energy storage devices connected to and charged by the distribution system are to be protected against the defined effects of electrical faults in the system.

23.12.8 Energy stores connected to and charged by the distribution system are to be so located and provided with arrangements allowing for the safe isolation of their terminals and the reduction of voltages to a safe level during maintenance or provided with alternative arrangements providing an equivalent level of safety which will be subject to special consideration.

23.12.9 Energy stores are to be connected to the distribution system by protection devices which include but are not limited to overcurrent and short circuit protection. The protective devices used are to be selective, ensuring faults are not transmitted further, independent of the direction of current flow.

23.13 Hybrid electrical power system components - Consumer of electrical power

23.13.1 Functional requirements: To convert electrical power supplied from the hybrid power generation and distribution system into useful work.

23.13.2 Rotating machines within consumers of electrical power are to comply with the requirements of *Pt 16, Ch 2, 9 Rotating machines*.

23.13.3 Converters within consumers of electrical power are to comply with the relevant requirements of *Pt 16, Ch 2, 23.11 Hybrid electrical power system components - Source of electrical power 23.11.6*.

23.13.4 Where a converter is arranged to step down voltage to provide a lower voltage supply to consumers than that of the power system then arrangements are to be provided to ensure the lower voltage distribution consumers are not subjected to voltage variations, including fast transients, outside their safe operating regions.

23.13.5 Consumers employing loads characterised by constant power characteristics connected to the distribution system through a converter are to be evaluated with respect to ensuring the stability of the power system as part of the power system analysis detailed in *Pt 16, Ch 2, 23.24 Power system development and integration - Power system analysis*.

23.14 Hybrid electrical power system components - Combined sources of electrical power, stores of electrical energy and consumers of electrical power

23.14.1 Functional requirements: To provide the combined functional requirements of each of the elements (sources, stores, consumers) from which the combination is constructed.

23.14.2 Where a single functional or physical assembly contains a combination of source, store or consume functions then it is to comply with the requirements of each applicable function as detailed in *Pt 16, Ch 2, 23.11 Hybrid electrical power system components - Source of electrical power* to *Pt 16, Ch 2, 23.13 Hybrid electrical power system components - Consumer of electrical power*.

23.15 Hybrid electrical power system components - Distribution system

23.15.1 Functional requirements:

(a) To provide a dependable interconnection between sources, stores and consumers of electrical power; and
(b) To distribute electrical power safely to consumers.

23.15.2 Arrangements for isolation and switching are to be provided which are to enable safe isolation of faults and for maintenance.

23.15.3 Distribution systems supplying consumers through converters are to provide galvanic isolation and ground separation.

23.15.4 In addition to the requirements of *Pt 16, Ch 2, 5.3 Isolation and switching*, systems are to comply with the requirements of *Pt 16, Ch 2, 23.15 Hybrid electrical power system components - Distribution system 23.15.5* to *Pt 16, Ch 2, 23.15 Hybrid electrical power system components - Distribution system 23.15.13*.

23.15.5 Where consumers are supplied via converters which are connected to both sides of a distribution system that is capable of being split, arrangements are to be provided to eliminate the risk of current being supplied back to the distribution system for example through flyback diodes.

23.15.6 Converters connecting sources, stores and consumers connected to the distribution system are to facilitate the connection and removal of sources, stores and consumers in a stable manner with the electrical power system in operation.

23.15.7 Converters are to be designed to prevent damage to the converter when switching under load.

23.15.8 Where essential services are required to be duplicated, these are to be served by individual circuits, separated in their switchboard or section board and throughout their length as widely as is practicable without the use of common feeders, protective devices, control circuits or controlgear assemblies, so that any single fault will not cause the loss of both services.

23.15.9 The distribution system is to be split into at least two independent systems each capable of independent operation or is to be separated by protection devices that are selective, ensuring faults are not transmitted further, and operate independent of the direction of current flow.

23.15.10 The distribution system is to be protected against electrical faults including short circuit, overload, earth fault, differential current, under/over voltage, under/over frequency, power quality, current and voltage imbalance, arc fault in compliance with the relevant requirements of *Pt 16, Ch 2, 6 System design - Protection* and *Pt 16, Ch 2, 23.15 Hybrid electrical power system components - Distribution system 23.15.11* to *Pt 16, Ch 2, 23.15 Hybrid electrical power system components - Distribution system 23.15.14*.

23.15.11 Active components may be used for the limitation of fault currents subject to verification in a real environment of the performance of the component under all normal and reasonably foreseeable abnormal operating and fault conditions and subject to establishment of effective surveillance and periodic test procedures during operation and maintenance in the ship's operating manuals to verify the component is capable of performing its intended function. An isolation device is to be provided within the component and this is to be tripped automatically in the event of the component operating. A risk assessment of the component is to be undertaken to a recognised standard that is acceptable to LR (e.g. ISO 31010, *Risk management – Risk assessment techniques*) and in accordance with *ShipRight Procedure Assessment of Risk Based Designs* and associated annexes.

23.15.12 Where energy management functionality provides protection against incorrect or unexpected energy flows between the sources, stores and consumers forming part of the hybrid electrical power system the sensors used for this purpose in the distribution system are to be independent of those used for control, monitoring and safety systems.

23.15.13 Where a bi-directional flow of power may occur, the distribution system is to withstand the power variations being introduced. The level of bi-directional flow allowed is to be specified by the system designer.

23.15.14 For **Hybrid Power (+)** notation facilities are to be provided for automatic detection of the location of insulation breakdown with respect to earth of equipment and distribution systems to a level determined by the integrator consistent with the system's dependability targets and agreed with the designers and Owners.

23.15.15 For either notation, switchgear and controlgear are to comply with the relevant requirements of *Pt 16, Ch 2, 7 Switchgear and controlgear assemblies*.

23.15.16 Power converters within distribution systems are to comply with the relevant requirements of *Pt 16, Ch 2, 23.11 Hybrid electrical power system components - Source of electrical power 23.11.6*.

23.15.17 Where fuses are implemented to limit the fault current in the converter, the activation of the protection is not to influence redundant consumers or cause loss of other single consumers as required by *Pt 16, Ch 2, 5.2 Essential services*.

23.15.18 Fuses used to protect distribution converters are to be of the bolted type. Where alternative arrangements are proposed, it is to be demonstrated that protection system's selectivity is not adversely affected as a result of an increased connection resistance.

23.15.19 For each section of a d.c. bus there is to be at least one voltmeter per section. An ammeter is to be provided for each converter supplying a d.c. bus. Similar arrangements are to be provided for screen-based displays.

23.15.20 The meters required by *Pt 16, Ch 2, 23.15 Hybrid electrical power system components - Distribution system 23.15.19* are to be located and arranged such that they may be viewed at a single operating position. In addition, meters may be required at additional locations to mitigate hazards identified by the risk assessment required by *Pt 16, Ch 2, 23.27 Power system development and integration - System Failure Modes and Effects Analysis (FMEA)*.

23.15.21 Power quality assessments are to consider the detection and impacts of circulating currents such as may exist through capacitive coupling in semiconductor converters.

23.15.22 Constant current distribution systems will be subject to special consideration and are not covered by these Rules.

23.15.23 For **Hybrid Power (+)** notation warnings of degrading power quality are to be provided and in the event of power quality exceeding prescribed limits automatic isolation and reconfiguration of the power system is to occur as agreed between the designers and owners.

23.16 Hybrid electrical power system components - Energy management

23.16.1 Functional requirements:

(a) To ensure that sufficient energy is available to satisfy the main power demand under all foreseeable operational conditions.
(b) To inform Operators as soon as reasonably practicable of deviations from normal operation of the hybrid electrical power system under all normal and reasonably foreseeable abnormal operational conditions.
(c) To initiate immediate corrective action on detection of component faults in the hybrid electrical power system that present a danger, reducing the risk to a level that is acceptable to LR.
(d) To provide functionality beyond the scope of conventional power management that is necessary for the control, monitoring, protection and dependability of the hybrid electrical power system.

23.16.2 Programmable electronic systems used to provide energy management functionality, or to provide safety functions, are to have arrangements which satisfy the applicable requirements of *Pt 16, Ch 1, 2 Essential features for control, alarm, monitoring and safety systems*.

23.16.3 Proposed modifications to software, including parameter changes, and during acceptance testing and trials are to be in accordance with *Pt 16, Ch 1, 1.4 Alterations and additions* as applicable.

23.16.4 Loss of energy management functionality is not to compromise the supply of main power, the safety of the ship, the hybrid electrical power system, or its components.

23.16.5 Energy management functionality is to include, but not be limited to, the following:

(a) Control (of the complete system and of each of its sub-systems):
    (i) Hybrid electrical power system operating mode selection and transition;
    (ii) Connection and disconnection of sources, stores and consumers to the distribution system in response to operating conditions and prevailing loads;
    (iii) Connection and disconnection of distribution system sections;
    (iv) Load allocation to and sharing between sources;
    (v) Load restriction of consumers;
    (vi) Energy flow management;
    (vii) Distribution system a.c. voltage and frequency and d.c. voltage; and
    (viii) Control functions required by sources, stores, consumers or distribution system that are necessary for their operation under all reasonably foreseeable normal, abnormal and fault conditions.
(b) Alarm and monitoring:
    (i) Mode transition status;
    (ii) Connection status of sources, stores, consumers and distribution system sections;
    (iii) Energy flows within the hybrid electrical power system and between its constituent parts;
    (iv) Power quality as detailed in *Pt 16, Ch 2, 23.17 Transversal requirements 23.17.3*; and
    (v) For stores, state of charge and state of health as defined in *Pt 16, Ch 2, 23.12 Hybrid electrical power system components - Store of electrical energy 23.12.4* and *Pt 16, Ch 2, 23.12 Hybrid electrical power system components - Store of electrical energy 23.12.5*.
(c) Protection and safety:
    (i) Blackout prevention;
    (ii) Blackout recovery;
    (iii) Detection of abnormal or unexpected energy flow as described in *Pt 16, Ch 2, 23.15 Hybrid electrical power system components - Distribution system 23.15.12*; and
    (iv) Safety functions required by sources, stores, consumers or distribution system that are necessary for their safe operation.

23.16.6 Overall ship-wide energy management functionality is to be integrated and coordinated with the functionality of the local management systems as described in *Pt 16, Ch 2, 23.3 Definitions* for each of the components (sources, stores, consumers, combinations, distribution system) of the hybrid electrical power system and is to ensure safe operation of the ship under all normal and reasonably foreseeable abnormal operating and fault conditions.

23.16.7 Additional energy management functionality for **Hybrid Power (+)** notation is to consider, but not be limited to, the following. The level of functionality supplied is to be consistent with the enhanced performance and dependability required by the system.

(a) Control (of the complete system and of each divisible element):
  (i) Automatic configuration of the power system based on predicted energy flow;
  (ii) Automatic system isolation and reconfiguration such that, in the event of a single failure in electrical power sources, stores, distribution system or associated control systems, the impact on the operational performance of the ship is as agreed with LR and there is no impact on the ship's ability to complete its mission;
  (iii) System performance optimisation, independent of primary control functions covering emissions, efficiency, availability, reliability or operating cost; and
  (iv) Control of stores with load smoothing, peak shaving, dynamic response or other optimisation capability.
(b) Alarm and monitoring:
  (i) Degradation of power quality;
  (ii) Remaining time for continued operation of the power system at current operating conditions and levels of power consumption. This may take the form of a real-time performance capability plot;
  (iii) System performance covering energy consumption, emissions, efficiency, availability, reliability or operating cost; and
  (iv) Health and condition of hybrid electrical power system components including the effects of ageing on electrical energy storage devices.
(c) Protection and safety:
  (i) Automatic isolation and reconfiguration of the power system on detection of abnormal energy flow;
  (ii) Consequence analysis determining the remaining time for continued operation of the power system under stated operating and load conditions following the most significant single failure. This may take the form of an onboard off-line simulation derived from, or an integral element of, the simulation described in *Pt 16, Ch 2, 23.23 Power system development and integration - Energy flows 23.23.3*; and
  (iii) Automatic detection of faults detailed in the system level FMEA with display of mitigating actions.

23.16.8 A description of functionality including also any functions not described in *Pt 16, Ch 2, 23.16 Hybrid electrical power system components - Energy management 23.16.5* and *Pt 16, Ch 2, 23.16 Hybrid electrical power system components - Energy management 23.16.7* is to be submitted.

23.17 Transversal requirements

23.17.1 All electrical equipment is to prevent injury to personnel or damage to other equipment and is to be suitably protected against damage to itself under normal, reasonably foreseeable abnormal and fault conditions.

23.17.2 The supply of electrical power sufficient for the correct operation of electrical services for essential equipment and habitable conditions is to be maintained:

(a) during all normal and reasonably foreseeable abnormal operating and fault conditions;
(b) irrespective of the direction of the propulsion shaft rotation; and
(c) without any requirement to revert to emergency supplies.

23.17.3 Hybrid electrical power systems are to provide a power quality as required by;

- *Pt 10, Ch 1, 7.3 Auxiliary and emergency engine governors* ,
- *Pt 16, Ch 2, 1.8 Quality of power supplies*,
- *Pt 16, Ch 2, 2.4 Prime mover governors* and
- *Pt 16, Ch 2, 9.4 Generator control*

during all normal and reasonably foreseeable abnormal operating and fault conditions.

23.17.4 A.c. and d.c. systems are during all normal and reasonably foreseeable abnormal operating and fault conditions to provide a quality of power as required by a recognised National or International Standard specified by the power system integrator that is acceptable to LR.

23.17.5 All components of or connected to the distribution system are to be designed and validated for operation across the full range of power quality conditions detailed in *Pt 16, Ch 2, 23.17 Transversal requirements 23.17.2* to *Pt 16, Ch 2, 23.17 Transversal requirements 23.17.4*.

23.17.6 The key parameters of power quality as determined by the system integrator with agreement of the owner and as applicable to the type of electrical power system are to be monitored and recorded for each individually operable section of the distribution system. An alarm is to be raised at a monitored operating station in the event of power quality exceeding limits determined by the system integrator in compliance with the power quality requirements of the rules. A description of the arrangements provided is to be submitted.

23.17.7 For either notation, all electrical equipment is to comply with the requirements of *Pt 16, Ch 2 Electrical Engineering* including:

(a) General requirements - *Pt 16, Ch 2, 1 General requirements* including fire, electric shock, ignition, radiation, fire, environment;
(b) Creepage and clearance - *Pt 16, Ch 2, 7.5 Creepage and clearance distances*;
(c) Arc - *Pt 16, Ch 2, 8 Protection of personnel from hazards resulting from electric arcs within electrical equipment assemblies and enclosures*; and
(d) Explosive atmospheres - *Pt 16, Ch 2, 14 Electrical equipment for use in explosive atmospheres*.

23.17.8 The choice of materials and components of construction, as well as the design, location and ship installation, are to be made according to the environmental, maintenance and operating conditions in order to maintain the continued function of the equipment during all normal and reasonably foreseeable abnormal conditions and to reduce the risk of:

(a) injury to onboard personnel;
(b) damage to the equipment the system is contained within or adjacent equipment and systems;
(c) damage to adjacent equipment and systems; and
(d) damage to the ship.

23.17.9 Where applicable, equipment and components are to be selected from the list of LR type approved products satisfying the requirements of *Pt 16, Ch 1, 1.3 Control, alarm and safety equipment* and *Pt 16, Ch 1, 2.13 Programmable electronic systems – Additional requirements for essential services and safety critical systems*.

23.17.10 Electrical equipment is to be used within its designed operating parameters, such as current, voltage, power, charging rate, energy storage, etc. to prevent:

(a) a hazard occurring; and
(b) the equipment affecting safety functions.

23.17.11 All electrical equipment supplied from the main and emergency sources of electrical power and electrical equipment for essential and emergency services is to be selected to operate satisfactorily under the variations of voltage and ripple frequencies which may be present in the system.

23.17.12 Cables and busbars are to be selected and installed in accordance with *Pt 16, Ch 2, 11 Electric cables, optical fibre cables and busbar trunking systems (busways)*.

23.17.13 Transformers within the hybrid electrical power system are to comply with the relevant requirements of *Pt 16, Ch 2, 10.1 Transformers*.

23.17.14 Interlocks or an alternative acceptable to LR are to be provided which will prevent access to capacitors until their voltage level has reduced to below the safe extra low voltage level (50 V); this is to ensure safety of personnel during maintenance.

23.18 Power system development and integration - General

23.18.1 The activities specified in *Pt 16, Ch 2, 23.19 Power system development and integration - System operational concept* to *Pt 16, Ch 2, 23.31 Verification requirements* are to be undertaken to deliver and maintain a safe and dependable hybrid electrical power system throughout its development, detail design, construction, integration, verification and acceptance. Procedures are to be made available detailing how these activities will be maintained during ship operation, maintenance and disposal.

23.18.2 The activities should be based on the principles of the following five levels with measures adopted at each level being, as far as practicable, independent of each other:

(a) Prevention of abnormal operation and failures though design and high quality in construction, operating rules and normal operating procedures;
(b) Control of abnormal operation and detection of failures through control, limiting and protection systems, monitoring/ surveillance features and abnormal/emergency operating procedures;
(c) Control of hazards within the system design to protect against escalation to an incident or accident through engineered safety features and emergency operating procedures;

(d) In support of and coordinated by the Owner and ship designer, control of severe ship or infrastructure conditions that may exceed the system design intent including prevention of hazard progression and mitigation of hazardous consequences through complementary procedures and hazard management; and
(e) In support of and coordinated by the Owner and ship designer, mitigation of accident consequences through emergency response.

The system designer is to ensure adoption of principles (a) to (c) during the development and integration of the hybrid electrical power system providing evidence to LR through the documentation that is submitted for design review as detailed in *Pt 6, Ch 2, 1.2 Documentation required for design review 1.2.13*.

23.18.3 At each phase of a project integration activities are to be managed by a suitably competent single designated party and are to be carried out in accordance with a defined procedure identifying the roles, responsibilities and requirements of all parties involved.

23.18.4 Where the designated party changes during a project then there is to be a full and auditable transfer of necessary integration information between the parties.

23.18.5 Systems engineering processes are to comply with *ISO 15288 Systems and Software Engineering – System Life Cycle Processes* or an acceptable equivalent National or International Standard.

23.19 Power system development and integration - System operational concept

23.19.1 The system operational concept is to be defined including a description of how the control, alarm and safety systems for the hybrid electrical power system provide effective means for operation and control during all defined ship operational conditions.

23.19.2 The system operational concept is to detail the capability, functionality and modes of operation under defined operating and emergency conditions and is to be agreed between the designers and Owners.

23.19.3 The system operational concept is to be submitted for design review.

23.20 Power system development and integration - Operating modes

23.20.1 Operating modes for the hybrid electrical power system are to be defined and agreed between the designers and Owners.

23.20.2 Modes are to cover all normal and reasonably foreseeable abnormal operating and fault conditions.

23.20.3 Modes are to be compatible with the ship's overall operating modes.

23.20.4 The sequence of transition between operating modes is to be defined for all normal and reasonably foreseeable abnormal operating and fault conditions.

23.20.5 A technical description is to be produced specifying for each of the ship's possible operating modes:

(a) the type of each electrical power source used to supply the distribution system, such as a.c. generators, d.c. generators, converter, batteries, fuel cells and photovoltaics;
(b) the operating mode of each electrical power source such as constant voltage, constant current or variable voltage;
(c) the configuration of the electrical distribution system, including the earthing and protection strategies to be used; and
(d) the worst-case failure design intent.

23.21 Power system development and integration - Consumer categorisation

23.21.1 Consumers supplied with electrical power from the hybrid electrical power system are to be categorised according to their function and the services that they provide in accordance with the requirements of *Pt 16, Ch 2, 1.6 Definitions*.

23.22 Power system development and integration - System components

23.22.1 The specifications for all components of the hybrid electrical power system (sources, stores, consumers, distribution system, energy management) are to be validated by the system designer for completeness and correctness in respect of the component's integration into the overall power system. Validated specifications are to be submitted to LR.

23.22.2 Details of the following are to be specified:

(a) Operating modes and the transition between them;
(b) Control and monitoring functions;

(c) Mechanical components which might affect the hybrid notation (e.g. cooling units with piping arrangements, pumps, valves, etc.);
(d) Safety functions;
(e) Failure modes;
(f) Isolation;
(g) Initial and through-life verification of conformance; and
(h) Human element.

23.23 Power system development and integration - Energy flows

23.23.1 Energy flows within the hybrid electrical power system are to be determined for all operating modes and all normal and reasonably foreseeable abnormal operating and fault conditions.

23.23.2 The impact of transition between modes on energy flow is to be considered.

23.23.3 For **Hybrid Power (+)** notation energy flow is to be modelled by a dynamic simulation that can be exercised under normal, reasonably foreseeable abnormal operating and fault conditions and that is maintained for the life of the ship. This simulation may be deployed on board as described in *Pt 16, Ch 2, 23.16 Hybrid electrical power system components - Energy management 23.16.7* in support of off-line consequence analysis.

23.23.4 Simulation tools are to conform to appropriate National or International Standards relevant to their use and are to have been validated in an equivalent application.

23.23.5 The dynamic simulation is to be verified against the energy flows encountered during the ship's real performance to the extent that this is reasonably practicable.

23.23.6 Proprietary simulation tools not conforming to an appropriate National or International Standard will be subject to special consideration. This consideration will include:

(a) Pedigree of the underlying modelling platform on which the simulation is built;
(b) Qualitative assessment of the simulation's functional capabilities and model behaviours;
(c) Configuration management of the simulation model, its architecture, functional blocks and the parameters on which it is based;
(d) Prior quantitative assessment of the simulation's performance in a similar application; and
(e) An engineering justification that the validation and verification of the simulation is sufficient to enable its application in all normal and reasonably foreseeable abnormal operating and fault conditions.

23.24 Power system development and integration - Power system analysis

23.24.1 The hybrid electrical power system is to be analysed for its electrical performance under all defined operating modes and all normal and reasonably foreseeable abnormal operating and fault conditions.

23.24.2 The analysis is to include, but not be limited to:

(a) Fault levels under short circuit conditions;
(b) Fault flows under short circuit and overload conditions;
(c) Protection device operation, discrimination and coordination;
(d) Quality of power supplies;
(e) Steady state performance;
(f) Transient performance;
(g) Earth fault currents;
(h) Resonance; and
(i) Common mode and circulating currents.

23.24.3 Information regarding the expected resistance, inductance and capacitance in the system and the installed components is to be provided as part of the analysis study as required by *Pt 16, Ch 2, 1.2 Documentation required for design review*. The values chosen are to be based upon the component tolerances which result in the worst case for each aspect of the analysis and are to be updated with actual values when determined from component, sub-system or system test.

23.24.4 For **Hybrid Power (+)** notation the analysis is to be by a dynamic simulation that can be exercised under all normal, abnormal and fault conditions, that is maintained for the life of the ship and that can be exercised to verify operation of the protection system including:

(a) Short circuit, single or multiple phases/poles;
(b) Overload;
(c) Overcurrent;
(d) Current imbalance;
(e) Voltage imbalance;
(f) Zone protection;
(g) Arc fault;
(h) Earth fault;
(i) Under/over voltage;
(j) Under/over frequency;
(k) Harmonic content;
(l) Quality of power supplies including degradation detection;
(m) Energy flow including any regeneration by consumers;
(n) Resonance and stability;
(o) Transient impact of fault detection, clearance and isolation;
(p) Transient impact of sources, stores and consumers being tripped or shut down;
(q) Transient impact of load changes, both increase and decrease; and
(r) Load sharing imbalance.

23.24.5 Simulation tools are to conform to appropriate National or International Standards relevant to their use and are to have been validated in an equivalent application.

23.24.6 The dynamic simulation is to be verified against the ship's real performance to the extent that this is reasonably practicable.

23.25 Power system development and integration - Safety functions

23.25.1 Safety functions related to the hybrid electrical power system and its constituent parts are to be clearly defined covering their purpose, their functionality and their location.

23.25.2 Safety functions are to comply with *Pt 16, Ch 1, 2 Essential features for control, alarm, monitoring and safety systems*.

23.25.3 Safety functions including ESD, emergency stop and reversionary control procedures for the hybrid electrical power system are to be defined, fully documented and made available to the Operators, maintainers and regulatory authorities.

23.26 Power system development and integration - Risk assessment

23.26.1 Where the hybrid electrical power system introduces new technologies or topologies not covered by the current Rules and Regulations then a risk assessment study is to be carried out.

23.26.2 A formal method acceptable to LR is to be used to determine if new hazards or significantly greater hazards than those normally associated with the ship electrical power system that would be mitigated by compliance with the Rules and Regulations have been introduced (e.g. a preliminary hazard analysis or a structured checklist approach (HAZID) in accordance with ISO 31010, *Risk management – Risk assessment techniques*).

23.26.3 Where the results of this formal method establish that new hazards or topologies exist the risk assessment study is to be undertaken to a recognised standard that is acceptable to LR (e.g. ISO 31010, *Risk management – Risk assessment techniques*) and in accordance with *ShipRight Procedure Assessment of Risk Based Designs* and the associated annexes.

23.26.4 The objectives of the study are to:

(a) identify potential deviations from the intended operation of the hybrid electrical power system;
(b) identify the causes of each deviation, and the consequences for safety and dependability;
(c) list safeguards to minimise causes and consequences; and
(d) determine and recommend if further safeguards should be considered.

23.26.5 The scope of the study is to consider normal operation, start-up, normal shutdown, non-use, and ESD of the hybrid electrical power system.

23.26.6 The risk assessment technique(s) selected are to be appropriate for their intended use and are to be accepted by LR.

23.27 Power system development and integration - System Failure Modes and Effects Analysis (FMEA)

23.27.1 An overall hybrid electrical power system FMEA is to be undertaken. The objectives of the analysis are to identify:

(a) potential failures;
(b) consequences of failure on the hybrid electrical power system and on ship operations;
(c) means to eliminate or prevent failure; and
(d) means to eliminate or minimise consequences.

23.27.2 The analysis may identify the requirement for safety measures in addition to those specifically stated in these Rules. Where additional safety measures are identified, evidence is to be provided that demonstrates how they are implemented and validated.

23.27.3 As a minimum, the scope of the analysis is to consider the 'fail safe' condition, location and arrangement of the critical system elements.

23.27.4 The analysis is to be undertaken to a recognised standard (e.g. IEC 60812, *Analysis techniques for system reliability – Procedure for failure mode and effects analysis (FMEA)*), or an equivalent and acceptable National or International Standard.

23.27.5 The FMEA is to consider but not be limited to:

(a) Hidden faults that are not annunciated to or evident to the Operator where a second subsequent fault can directly result in a significant failure and hazardous condition;
(b) Foreseeable inadvertent operation of the hybrid electrical power system;
(c) Failure to complete transition sequences (e.g. change of operating mode or response to a fault including its detection, clearance, isolation and reconfiguration);
(d) Items which can be dormantly failed and unavailable to perform their intended operation on demand (e.g. normal to backup changeover systems or standby start systems);
(e) Enabling systems not part of the hybrid electrical power system (e.g. fuel supply, lubrication, cooling and ventilation systems) whose failure could affect correct functioning of the hybrid electrical power system;
(f) Sensor and feedback errors in programmable electronic systems;
(g) Parameter corruption in programmable electronic systems (e.g. incorrect scaling factors, control rates, alarm thresholds or trip levels);
(h) Common cause effects in programmable electronic systems (e.g. network storms in networked systems, power supply faults, time dependent errors in operating systems with the potential to concurrently impact multiple redundant control or monitoring systems);
(i) Common cause effects in electrical power systems (e.g. power quality outside expected range or multiple earth faults in a parallel connected system);
(j) Consequential failures resulting from a single failure that are to be considered as an integral part of the single failure; and
(k) The viability of the role of the human in the detection and mitigation of faults.

23.27.6 Examples of devices in which hidden failures can occur that are detrimental to the dependability of a hybrid electrical power system include but are not limited to:

(a) Protection devices – protection relays, dead-bus sensing;
(b) Automatic isolation devices;
(c) Circuit breaker open/close/trip functions;
(d) Fault/current limitation devices;
(e) Arc detection;
(f) Load shedding devices;
(g) Safety devices;
(h) Fault detection systems;
(i) Alternator current boost systems;
(j) Interlocks and inter-trips;
(k) Automatic change-over systems, transfer and dual-feed arrangements;
(l) Stand-by start arrangements;
(m) Transducers/sensors – giving an incorrect output;
(n) Slow processors (e.g. watchdog functions);
(o) UPS backed-up supplies; and

(p) Active failures of control systems – working but not doing what was intended.

23.27.7 Hybrid electrical power system failure modes identified through the FMEA that could impact the safe operation and performance of any component of the system (source/store/consumer/combination/distribution system/energy management) are to be notified to, and acknowledged by, the party accountable for the safety of the component through an auditable process.

23.27.8 Component failure modes that could impact the safe operation and performance of the hybrid electrical power system are to be notified to, and acknowledged by, the hybrid electrical power system integrator through an auditable process.

23.27.9 For **Hybrid Power (+)** notation FMEAs for each of the key components of the system may be requested by LR in support of the system FMEA.

23.28 Power system development and integration - Operating instructions

23.28.1 Operating Manuals are to be provided on board and submitted for information where requested by LR. The manuals are to include, but not be limited to, the following information:

(a) Particulars and a description of the systems;
(b) Operating instructions for the equipment and systems (including fire isolation aspects);
(c) Maintenance instructions for the installed arrangements, including procedures to prevent injury from electric shock and arc flash;
(d) Software configuration management procedures which are to include a list of all versions of the software installed in the system, and the settings, values of system or equipment specific configuration parameters; and
(e) Output from the risk assessment processes that is necessary for the safe operation of the system under all normal and reasonably foreseeable abnormal operating conditions.

23.28.2 Overall hybrid electrical power system operating instructions are to be verified by the system designer for their completeness and correctness in all operating modes and for all foreseeable normal and abnormal operating and fault conditions. The verified instructions are to be submitted to LR.

23.28.3 Consistency between the overall system instructions and those for each component of the system is to be confirmed by the system designer.

23.28.4 All mitigating actions arising from the FMEA that require manual intervention are to be confirmed as included in the operating instructions.

23.28.5 Procedures for reversionary (e.g. manual) control of the hybrid electrical power system are to be included and are to be verified during practical operation.

23.29 Power system development and integration - Operator training

23.29.1 Training needs specific to the ship and necessary for its safe operation are to be identified and documented in the ship's operating manual.

23.29.2 For **Hybrid Power (+)** notation any ship-specific Operator training is to be verified by the system designer for its completeness and correctness in all operating modes and for all foreseeable normal and abnormal operating and fault conditions with evidence of verification submitted to LR.

23.30 Power system development and integration - Through-life accountability

23.30.1 The activities detailed in *Pt 16, Ch 2, 23.18 Power system development and integration - General* to *Pt 16, Ch 2, 23.29 Power system development and integration - Operator training* are to be maintained throughout the whole lifecycle of a ship and are to be verified at Periodic Survey.

23.30.2 Proposed changes to the hybrid electrical power system including its components that may impact on system safety or dependability are to be formally reviewed and accepted by the system integrator before their incorporation with details submitted to LR.

23.30.3 For **Hybrid Power (+)** notation details of incidents arising during any and all operations of the hybrid electrical power system that has, or could have, resulted in a hazardous consequence for people, platform or the environment are to be monitored.

23.31 Verification requirements

23.31.1 Compliance with the requirements in *Pt 16, Ch 2, 1.2 Documentation required for design review 1.2.14* is deemed to satisfy the functional requirements and performance requirements above.

23.32 Testing and trials

23.32.1 Testing and trials in accordance with *Pt 16, Ch 2, 21 Testing and trials* are to be carried out as applicable.

23.32.2 Where required by the *Rules and Regulations for the Classification of Special Service Craft, July 2021*, items are to be constructed under survey.

23.32.3 Materials are to be approved, manufactured and tested in accordance with a standard acceptable to LR.

23.32.4 The fault ride-through capability of the system is to be demonstrated during practical tests on the system.

23.32.5 Quality of power supply testing of the system and the components is to be carried out to prove the equipment is capable of operating under the variations specified by the hybrid electrical power system integrator and accepted by LR for all normal and reasonably foreseeable abnormal operating conditions.

23.32.6 Where considered necessary by LR, additional testing may be required.

23.32.7 Satisfactory operation and load testing of the hybrid electrical power system in harbour and during sea trials are to be witnessed by LR.

23.32.8 Measurements are to be taken as part of the trials to verify that the installation will provide a quality of power supply in accordance with the values declared by the hybrid electrical power system integrator as described in *Pt 16, Ch 2, 23.17 Transversal requirements*.

23.32.9 For **Hybrid Power (+)** notation additional trials are to be carried out to:

(a) Verify that the system delivers the determined levels of performance as described in *Pt 16, Ch 2, 23.5 Hybrid electrical power system performance - System performance targets*;

(b) Verify that the system fulfils the redundancy principles defined by the hybrid electrical power system integrator as described in *Pt 16, Ch 2, 23.6 Hybrid electrical power system performance - Dependability principles*;

(c) Verify the correct operation of the additional energy management functionality described in *Pt 16, Ch 2, 23.16 Hybrid electrical power system components - Energy management*;

(d) Verify that the system performs in accordance with its simulation(s) as described in *Pt 16, Ch 2, 23.23 Power system development and integration - Energy flows* and *Pt 16, Ch 2, 23.24 Power system development and integration - Power system analysis*; and

(e) Verify the findings of the FMEA analysis detailed in *Pt 16, Ch 2, 23.27 Power system development and integration - System Failure Modes and Effects Analysis (FMEA)* and the response of the system to simulated failures.

Contents

■ *Section 1* General requirements

1.1 Application

1.1.1 The requirements of this Part apply to yachts with a load line length greater than 24 m and service craft (*see also Pt 17, Ch 1, 1.1 Application 1.1.2.(e)* built in accordance with these Rules.

1.1.2 Consideration will be given to the acceptance of fire safety measures:

(a) which, for service craft, have been prescribed and approved by the Government of the Flag State, provided these are deemed acceptable by LR. In this instance, the requirements of *Pt 17, Ch 2 Fire Protection, Detection and Extinction – Service Craft* and *Pt 17, Ch 4 System and Equipment Specifications* of these Rules are not applicable;
(b) which, for yachts, have been prescribed and approved by the Government of the Flag State, provided these are deemed acceptable by LR. In this instance, the requirements of *Pt 17, Ch 3 Fire Protection, Detection and Extinction – Yachts* and *Pt 17, Ch 4 System and Equipment Specifications* of these Rules are not applicable;
(c) which, for yachts, intended for the carriage of more than 12 passengers but not more than 36 passengers, have been prescribed and approved by the Government of the Flag State, provided these are shown to be equivalent to those required by SOLAS for passenger ships carrying not more than 36 passengers. In this instance, the requirements of *Pt 17, Ch 3 Fire Protection, Detection and Extinction – Yachts* and *Pt 17, Ch 4 System and Equipment Specifications* of these Rules are not applicable;
(d) which, for yachts, intended for the carriage of more than 36 passengers, have been prescribed and approved by the Government of the Flag State, provided these are shown to be equivalent to those required by SOLAS for passenger ships carrying more than 36 passengers. In this instance, the requirements of *Pt 17, Ch 3 Fire Protection, Detection and Extinction – Yachts* and *Pt 17, Ch 4 System and Equipment Specifications* of these Rules are not applicable;
(e) where the arrangements are considered equivalent to those required by these Rules as a result of risk assessment studies; or
(f) where the arrangements are considered acceptable compared to those required by these Rules, due cognisance having been taken of any restricted service limits.

1.1.3 Special consideration, consistent with the fire hazard involved, will be given to construction or arrangements not covered by this Chapter.

1.1.4 High speed cargo craft of 500 gross tons and over on international voyages and high speed passenger craft on international voyages are to be provided with the fire safety measures required by the *International Convention for the Safety of Life at Sea, 1974* as amended (SOLAS 74), *Chapter X - Safety measures for high-speed craft* – Safety Measures for High Speed Craft (*International Code of Safety for High Speed Craft*).

1.1.5 High speed cargo craft of 500 gross tons and over employed on national voyages and high speed passenger craft employed on national voyages are to comply with the fire safety measures of the Government of the Flag State.

1.1.6 High speed cargo craft of less than 500 gross tons employed on national or international voyages are to comply with the fire safety measures of the Government of the Flag State.

1.1.7 It is the responsibility of the Government of the Flag State to give effect to the fire safety measures of *Pt 17, Ch 1, 1.1 Application 1.1.4*, *Pt 17, Ch 1, 1.1 Application 1.1.5* and *Pt 17, Ch 1, 1.1 Application 1.1.6*. However, Lloyd's Register (hereinafter referred to as LR) will undertake to do this in cases where:

(a) Contracting Governments have authorised LR to apply the requirements of SOLAS 74 and issue the appropriate certification on their behalf; or
(b) the Government of the Flag State is not a signatory to SOLAS 74; or

(c) the craft is to be classed for restricted or special service in national waters and the Government of the Flag State has no National requirements.

1.1.8 When implementing the provisions of *Pt 17, Ch 1, 1.1 Application 1.1.7*, LR will apply the fire safety measures required by SOLAS 74 *Chapter X - Safety measures for high-speed craft* – Safety Measures for High Speed Craft (*International Code of Safety for High Speed Craft*). However, due consideration will be given to arrangements deemed to provide an equivalent level of fire safety, taking due cognisance of the circumstances of the restricted or special service.

1.2 Submission of plans and information

1.2.1 The plans and information detailed in *Pt 17, Ch 1, 1.2 Submission of plans and information 1.2.2*, where applicable, are to be submitted at least in triplicate for approval, together with all additional information such as gross tonnage and number of passengers/guests.

1.2.2 For fire protection, the following plans and information are to be submitted:

(a) Structural fire protection plan showing extent of materials used in construction, steel, aluminium, or alternative forms of construction, together with details of the thermal characteristics of the alternative forms of construction that include the temperature at which the material starts to lose its strength, and proposals for protection, etc.
(b) A general arrangement plan showing the main fire zones, escape stairways and the fire compartmentation bulkheads and decks within the main fire zones, including the engine rooms, galleys, bonded stores, paint stores, navigating bridge, radio room, fire-fighting control room, emergency generator rooms and battery locker, helicopter arrangements, including re-fuelling and petrol stowage arrangements.
(c) A plan showing the details of construction of the fire protection bulkheads and decks and the particulars of any surface laminates employed.
(d) Copies of the Certificates of Approval by National Authorities and Fire Test Reports in respect of all `A' and `B' Class fire divisions, non-combustible materials and materials having low flame-spread characteristics, etc. which are to be used but have not been approved by LR. Copies of Certificates issued by other recognised approval bodies may be submitted for consideration.
(e) A ventilation plan showing ducts and any dampers in them, closing appliances and the position of the controls for stopping the system.
(f) A plan showing the fire detection and alarm system.
(g) A plan showing the remote control system for fire doors, if applicable.
(h) A fire control plan meeting the requirements of *Pt 17, Ch 4, 5 Fire-control plans*.

1.2.3 For fire-extinguishing the following plans are to be submitted:

(a) A general arrangement plan showing the disposition of all the fire-fighting equipment including the fire main, the fixed fire-extinguishing systems; the disposition of the portable and non-portable extinguishers and the types used; and the position and details of the firemen,s outfits.
(b) A plan showing the layout and construction of the fire main, including the main and emergency fire pumps, isolating valves, pipe sizes and materials, and the cross connections to any other system.
(c) A plan showing details of each fixed fire-fighting system, including calculations for the quantities of the media used and the proposed rates of application.

1.2.4 Fire-control plans as required by *Pt 17, Ch 4, 5 Fire-control plans* are to be submitted.

1.2.5 For yachts, where fire plans and the information listed above have been appraised, approved and verified on board by the Flag Administration LR will only acknowledge the aforementioned and therefore no further appraisal, approval or survey should be provided.

Section 2
Definitions

2.1 Materials

2.1.1 **Non-combustible material** means a material which neither burns nor gives off flammable vapours in sufficient quantity for self-ignition when heated to approximately 750°C, according to an established test procedure, *see* IMO *International Code for Application of Fire Test Procedures* (FTP Code), Annex 1, Part 1. Any other material is a **combustible material**.

2.1.2 **Steel or other equivalent material.** Where the words 'steel or other equivalent material' occur, 'equivalent material' means any non-combustible material which, by itself, or due to insulation provided, has structural and integrity properties equivalent to steel at the end of the applicable fire exposure to the standard fire test (e.g. aluminium with appropriate insulation).

2.1.3 **Alternative forms of construction** means any combustible material may be accepted if it can be demonstrated that the material, which by itself or due to insulation provided has structural and fire integrity properties equivalent to `A' or `B' class divisions, or steel, as applicable, at the end of the applicable fire exposure to the standard fire test.

2.2 Fire test

2.2.1 A **standard fire test** is one in which the specimens of the relevant bulkheads and decks are exposed in a test furnace to temperatures corresponding approximately to the standard time-temperature curve. The test methods are to be in accordance with the IMO FTP Code, Annex 1, *Part 3 - Test for “A”, “B” and “F” Class Divisions*.

2.3 Flame spread

2.3.1 **Low flame spread** means that the surface thus described will adequately restrict the spread of flame, having regard to the risk of fire in the spaces concerned, this being determined by an acceptable test procedure, *see* IMO FTP Code, Annex 1, *Part 5 - Test for Surface Flammability*

2.3.2 **Not readily ignitable** means that the surface thus described will not continue to burn for more than 20 seconds after the removal of a suitable impinging test flame.

2.4 Ship divisions and spaces

2.4.1 **'A' Class divisions** are those divisions formed by bulkheads and decks and:

(a) Are to be constructed of steel or other equivalent material.
(b) Are to be suitably stiffened.
(c) Are to be so constructed as to be capable of preventing the passage of smoke and flame up to the end of the one-hour standard fire test, *see Pt 17, Ch 1, 2.2 Fire test 2.2.1*.
(d) Are to be insulated with approved non-combustible materials such that the average temperature of the unexposed side will not rise more than 140°C above the original temperature, nor will the temperature, at any one point, including any joint, rise more than 180°C above the original temperature, within the time listed below:

Class `A-60'	60 minutes.
Class `A-30'	30 minutes.
Class `A-15'	15 minutes.
Class `A-0'	0 minutes.

(e) may be required to demonstrate that they meet the above requirements for integrity and temperature rise, through a test.

2.4.2 **'B' Class divisions** are those divisions formed by bulkheads, decks, ceilings or linings and:

(a) Are to be so constructed as to be capable of preventing the passage of flame to the end of the first half hour of the standard fire test, *see* IMO FTP Code, Annex 1, Part 3.

(b) Are to be insulated such that the average temperature of the unexposed side will not rise more than 140°C above the original temperature, nor will the temperature at any one point, including any joint, rise more than 225°C above the original temperature, within the time listed below:

Class `B-15'	15 minutes.
Class `B-0'	0 minutes.

(c) Are to be constructed of approved non-combustible materials and all materials entering into the construction and erection of `B' Class divisions are to be non-combustible, except where permitted by other requirements of this Chapter.

(d) May be required to ensure that they meet the above requirements for integrity and temperature rise through a test of a prototype division.

2.4.3 **'C' Class divisions** are divisions to be constructed of approved non-combustible materials. They need to meet neither requirements relative to the passage of smoke and flame nor limitations relative to the temperature rise. Combustible veneers are permitted provided they meet other requirements of this Chapter.

2.4.4 **Continuous `B' Class ceilings or linings** are those `B' Class ceilings or linings which terminate only at an `A' or `B' Class division.

2.4.5 **Accommodation spaces** are those spaces used for public spaces, corridors, lavatories, cabins, offices, hospitals, cinemas, games and hobbies rooms, pantries containing no cooking appliances and similar spaces.

2.4.6 **Service spaces** are those used for galleys, pantries containing cooking appliances, stores, mail and specie rooms, store rooms, lockers, workshops other than those forming part of the machinery spaces and similar spaces and trunks to such spaces.

2.4.7 **Cargo spaces** are all spaces used for cargo (including cargo oil tanks) and trunks to such spaces.

2.4.8 **Machinery spaces of Category A** are those spaces and trunks to such spaces which contain:

(a) internal combustion machinery used for main propulsion; or

(b) internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 kW; or

(c) any oil-fired boiler or fuel oil unit.

2.4.9 **Machinery spaces** are all machinery spaces of Category `A' and all other spaces containing propelling machinery, boilers, fuel oil units, steam and internal combustion engines, generators and major electrical machinery, oil filling stations, refrigerating, stabilising, ventilation and air conditioning machinery, and similar spaces; and trunks to such spaces.

2.4.10 **Control stations** are those spaces in which the craft's radio or main navigating equipment or the emergency source of power is located or where the fire recording or fire-control equipment is centralised.

2.4.11 **Cargo area** is that part of the ship that contains cargo tanks, slop tanks and cargo pump rooms including pump rooms, cofferdams, ballast and void spaces adjacent to cargo tanks and also deck areas throughout the entire length and breadth of the part of the craft over the above-mentioned spaces.

2.4.12 **Main vertical zones** are those sections into which the hull, superstructure and deck houses are divided by `A' Class divisions, the mean length and width of which on any one deck does not, in general, exceed 48 m.

2.5 Equipment

2.5.1 **Fuel oil unit** is the equipment used for the preparation of fuel oil for delivery to an oil-fired boiler, or equipment used for the preparation for delivery of heated oil to an internal combustion engine, and includes any oil pressure pumps, filters and heaters dealing with oil at a pressure of more than 1,8 bar (1,8 kgf/cm^2) gauge.

2.6 Craft types

2.6.1 For the purpose of this Part the definitions of craft types given in *Pt 17, Ch 1, 2.6 Craft types 2.6.2* and *Pt 17, Ch 1, 2.6 Craft types 2.6.3* apply.

2.6.2 A **passenger craft** is a craft which carries more than twelve passengers.

2.6.3 A **yacht** is a craft in commercial or non-commercial use for sport or pleasure and may be propelled mechanically, by sail or by a combination of both.

■ *Section 1* General requirements

1.1 Application

1.1.1 The requirements of this Chapter apply to craft built in accordance with these Rules for service groups **G1** to **G6**. For craft classed to service groups **Zone 1**, **Zone 2** or **Zone 3**, the criteria of the*Pt 6, Ch 3 Fire Protection, Detection and Extinction* of the *Rules and Regulations for the Classification of Inland Waterways Ships, July 2021* are to be applied.

1.1.2 Where service craft incorporate fire hazards not covered in this Part, appropriate fire protection, detection and extinction arrangements are to be provided. Details are to be submitted for approval.

■ *Section 2* Fire safety measures for service craft

2.1 General

2.1.1 *Table 2.2.1 General fire protection, detection and extinction requirements* is a guide to the major requirements of this Section. The Table is intended as a quick reference to the requirements and is not to be used in isolation when designing the fire safety arrangements.

2.2 Forms of construction – Structure

2.2.1 The hull, superstructure, structural bulkheads, decks and deckhouses may be constructed of steel, other equivalent material, *see Pt 17, Ch 1, 2.1 Materials 2.1.2* or be of alternative forms of construction, *see Pt 17, Ch 1, 2.1 Materials 2.1.3*.

2.2.2 The structure in way of Category ‘A' machinery spaces, galleys containing appliances of significant fire risk, *see Pt 17, Ch 2, 2.4 Structural fire protection 2.4.2*, and other high risk areas is to be protected such that the material by itself or due to insulation provided can maintain its required strength at the end of 30 minutes exposure to the standard fire test.

2.2.3 Details of the method of construction, supported by calculations and/or fire test data, demonstrating compliance with *Pt 17, Ch 2, 2.2 Forms of construction – Structure 2.2.2*, are to be submitted.

2.2.4 For aluminium alloy structures, the insulation is to be such that the temperature of the structural core does not rise more than 200°C above the ambient temperature at any time during the specified fire exposure.

Table 2.2.1 General fire protection, detection and extinction requirements

Form of construction, *see Pt 17, Ch 2, 2.2 Forms of construction – Structure*	Steel or equivalent, or alternative forms of construction may be accepted, subject to requirements in high fire risk areas
Passive fire protection,*see Pt 17, Ch 2, 2.3 Forms of construction – Fire divisions*	Category ‘A’ machinery spaces: • For craft >150 gross tons: A-30/A-0 • For craft <150 gross tons: A-0 Galleys: • For craft >50 gross tons: B-15

Means of escape, *see Pt 17, Ch 2, 2.7 Means of escape*:	
• Machinery spaces	2
• Accommodation, etc.	2
Fixed fire detection system, *see Pt 17, Ch 2, 2.13 Fixed fire detection and fire-alarm systems*	• Fitted in all machinery spaces • Fitted in stairways, service spaces, machinery spaces, control stations and accommodation spaces of craft >50 gross tons with sleeping accommodation
Fire pumps, *see Pt 17, Ch 2, 2.14 Fire pumps and fire main system*	• 1 fixed power pump + 1 portable pump • For craft <150 gross tons: 1 portable pump
Fire-extinguishing arrangements in machinery spaces, *see Pt 17, Ch 2, 2.15 Fire-extinguishing arrangements in Category ‘A' machinery spaces*	• A fixed fire-extinguishing system • A minimum of 2, but need not exceed 5 portable foam extinguishers or equivalent
Portable fire-extinguishers in accommodation, *see Pt 17, Ch 2, 2.18 Fixed fire-extinguishing systems not required by this Chapter*	Sufficient to ensure that at least one will be readily available in every compartment

2.2.5 For composite structures, the insulation is to be such that the temperature of the laminate does not rise more than the minimum temperature of deflection under load of the resin at any time during the specified fire exposure. The temperature of deflection under load is to be determined as in *Ch 14, 3.7 Tests for specific materials* of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

2.2.6 For structures in contact with sea-water, the required insulation should extend to at least 300 mm below the lightest waterline, *see also Pt 17, Ch 2, 2.6 Surface of insulation 2.6.1*.

2.3 Forms of construction – Fire divisions

2.3.1 Fire divisions required by *Pt 17, Ch 2, 2.4 Structural fire protection* are to be constructed in accordance with the remaining paragraphs of this sub-Section.

2.3.2 Fire divisions using steel equivalent or alternative forms of construction may be accepted if it can be demonstrated that the material by itself, or due to insulation provided, has the fire resistance properties equivalent to ‘A' or ‘B' class divisions.

2.3.3 Insulation required by *Pt 17, Ch 2, 2.3 Forms of construction – Fire divisions 2.3.2* is to be such that the temperature of the structural core does not rise above the point at which the structure would begin to lose its strength at any time during the applicable exposure to the standard fire test. For ‘A' class divisions, the applicable exposure is 60 minutes, and for ‘B' Class divisions, the applicable exposure is 30 minutes.

2.3.4 For aluminium alloy structures the insulation is to be such that the temperature of the structural core does not rise more than 200°C above the ambient temperature at any time during the applicable fire exposure.

2.3.5 For composite structures, the insulation is to be such that the temperature of the laminate does not rise more than the minimum temperature of deflection under load of the resin at any time during the applicable fire exposure. The temperature of deflection under load is to be determined as in *Ch 14, 3.7 Tests for specific materials*.

2.4 Structural fire protection

2.4.1 Category ‘A' machinery spaces are to be enclosed by A-30 Class divisions where adjacent to accommodation spaces, or control positions and A-0 Class divisions elsewhere. For craft below 150 gross tons, Category ‘A' machinery spaces are to be enclosed by A-0 Class divisions, regardless of adjacent space use.

2.4.2 For craft greater than 50 gross tons, galleys are to be enclosed by B-15 Class divisions unless the cooking appliances contained therein have an insignificant fire risk.

(a) For the purposes of this Chapter, coffee automats, toasters, dishwashers, microwave ovens, water boilers and similar appliances each with a maximum power of 5 kW may be regarded as having an insignificant fire risk. Electrically-heated

cooking plates and hot plates for keeping food warm, each of them having a maximum power of 2 kW and a surface temperature not above 150°C may also be regarded as having insignificant fire risk. If spaces containing this equipment are lockable, then means of cutting-off the power to the space are to comply with *Pt 16, Ch 2, 17.6 Fire safety stops 17.6.7*.

(b) Other equipment such as fat fryers, open flame cookers, etc. are to be regarded as having a significant fire risk.

2.4.3 Openings in ‘A' Class divisions are to be provided with permanently attached means of closing that are to be at least as effective for resisting fires as the divisions in which they are fitted.

2.4.4 Interior stairways serving machinery spaces, accommodation spaces, service spaces or control stations are to be of steel or other equivalent material.

2.4.5 Doors are to be self-closing in way of Category ‘A' machinery spaces.

2.4.6 Where ‘A' Class divisions are penetrated for the passage of electric cables, pipes, trunks, ducts, etc. or for girders, beams or other structural members, arrangements are to be made to ensure that the fire resistance is not impaired.

2.4.7 Where the structure or ‘A' Class divisions are required to be insulated, it is to be ensured that the heat from a fire is not transmitted through the intersections and terminal points of the divisions or penetrations to uninsulated boundaries. Where the insulation installed does not achieve this, arrangements are to be made to prevent this heat transmission by insulating the horizontal and vertical boundaries or penetrations for a distance of 450 mm.

2.5 Materials

2.5.1 Paints, varnishes and other finishes used on exposed interior surfaces are not to be capable of producing excessive quantities of smoke, toxic gases or vapours and are to be of the low flame spread type. Reference is also to be made to the IMO FTP Code, Annex 1, *Part 2 - Smoke and Toxicity Test* and *Part 5 - Test for Surface Flammability*.

2.5.2 Except in refrigerated compartments of service spaces, all insulation (e.g. fire and comfort) is to be of non-combustible materials.

2.5.3 Pipes penetrating ‘A' Class divisions are to be of approved materials having regard to the temperature such divisions are required to withstand.

2.5.4 Pipes conveying oil or combustible liquids through accommodation and service spaces are to be of approved materials having regard to the fire risk.

2.5.5 Materials readily rendered ineffective by heat are not to be used for overboard scuppers, sanitary discharges, and other outlets which are close to the waterline and where the failure of the material in the event of fire would give rise to danger of flooding.

2.5.6 Primary deck coverings within accommodation spaces, service spaces and control stations are to be of a type that will not readily ignite, or give rise to toxic or explosive hazards at elevated temperatures. Reference is also to be made to the IMO FTP Code, Annex 1, *Part 2 - Smoke and Toxicity Test* and *Part 6 - Test for Primary Deck Coverings*.

2.5.7 Vapour barriers and adhesives used in conjunction with insulation, as well as insulation of pipe fittings for cold service systems need not be non-combustible, but they are to be kept to the minimum quantity practicable and their exposed surfaces are to have low flame spread characteristics.

2.5.8 All waste receptacles are to be constructed of non-combustible materials with no openings in the sides or bottom.

2.6 Surface of insulation

2.6.1 In spaces where penetration of oil products is possible, the surface of insulation is to be impervious to oil or oil vapours. Insulation boundaries are to be arranged to avoid immersion in oil spillages.

2.7 Means of escape

2.7.1 Stairways, ladders and corridors serving crew spaces and other spaces to which the crew normally have access are to be arranged so as to provide ready means of escape to a deck from which disembarkation may be effected.

2.7.2 Where reasonable and practicable, and having regard to the number of crew and size of space, at least two means of escape, as widely separated as possible, are to be provided from each section of accommodation spaces, service spaces and control stations.

(a) The normal means of access to the accommodation and service spaces below the open deck is to be arranged so that it is possible to reach the open deck without passing through intervening spaces containing a possible source of fire.

(b) The second means of escape may be through portholes, or hatches of adequate size, leading to the open deck.

(c) No dead-end corridors having a length of more than 7 m will be accepted. A 'dead-end corridor' is a corridor or part of a corridor from which there is only one escape route.

2.7.3 At least two means of escape are to be provided from machinery spaces, except where the small size of the machinery space makes it impractical. Escape is to be by steel ladders that are as widely separated as possible.

2.8 Ventilation systems

2.8.1 Ventilation fans are to be capable of being stopped, and main inlets and outlets of ventilation systems closed, from outside the spaces being served, *see also Pt 16, Ch 2, 17.6 Fire safety stops*.

2.8.2 Ventilation ducts for Category ‘A' machinery spaces and exhaust ducts for galleys of significant fire risk are not to pass through accommodation spaces, service spaces or control stations unless the ducts are constructed of steel and arranged to preserve the integrity of the division.

2.8.3 Ventilation ducts for accommodation spaces, service spaces or control stations are not to pass through Category ‘A' machinery spaces unless the ducts are constructed of steel and arranged to preserve the integrity of the division.

2.8.4 Store-rooms containing highly flammable products are to be provided with ventilation arrangements that are separate from other ventilation systems. Ventilation is to be arranged to prevent the build-up of flammable vapours at high and low levels. The inlets and outlets of ventilators are to be positioned so that they do not draw from or vent into an area which would cause undue hazard, and are to be fitted with spark arresters.

2.8.5 Ventilation systems serving Category ‘A' machinery spaces are to be independent of systems serving other spaces.

2.8.6 All enclosed spaces containing free-standing fuel tanks are to be ventilated independently of systems serving other spaces.

2.8.7 Ventilation is to be provided to prevent the accumulation of dangerous concentrations of flammable gas that may be emitted from batteries. The requirements of *Pt 16, Ch 2, 12.5 Thermal management and ventilation* are to be complied with.

2.8.8 Ventilation openings may be fitted in and under the lower parts of cabin and public space doors in corridor bulkheads. Ventilation grills are to be of non-combustible material. The total net area of any such openings is not to exceed 0,05 m^2. Bridging ducts are not allowed in fire divisions.

2.8.9 For additional requirements for the ventilation of domestic gaseous fuel, *see Pt 17, Ch 2, 2.11 Arrangements for gaseous fuel for domestic purposes*.

2.9 Fuel arrangements

2.9.1 In service craft in which fuel oil is used, the arrangements for the storage, distribution and utilisation of the fuel oil are to be such as to ensure the safety of the service craft and persons on board. For details, *see Pt 15, Ch 3 Machinery Piping Systems*.

2.9.2 Fuel oil tanks situated within the boundaries of Category ‘A' machinery spaces are not to contain fuel oil having a flashpoint of less than 60°C.

2.9.3 Fuel oil, lubricating oil and other flammable oils are not to be carried in fore peak tanks.

2.10 Special arrangements in machinery spaces and, where necessary, other spaces

2.10.1 Openings are to be provided with closing appliances constructed so as to maintain the fire integrity of the machinery space boundaries.

2.10.2 The type of equipment installed and the layout of the craft are to take account of the risk and spread of fire. Special attention is to be paid to the surroundings of open flame devices, hot areas and main and auxiliary machinery, oil and fuel overflows, and uncovered oil and fuel pipes.

2.10.3 Fuel filling, storage, venting and supply systems are to be installed so as to minimise the risk of fire and explosion.

2.10.4 Machinery components and accessories that require frequent maintenance and inspection are to be readily accessible.

2.10.5 Windows are not to be fitted in machinery space boundaries. This does not preclude the use of glass in control rooms within the machinery spaces.

2.10.6 In Category ‘A' machinery spaces means of control are to be provided for:

(a) closure of openings which normally allow exhaust ventilation, and closure of ventilator dampers;

(b) permitting the release of smoke;

(c) stopping ventilating fans; and

(d) stopping forced and induced draught fans, fuel oil transfer pumps, fuel oil unit pumps and other similar fuel pumps.

2.10.7 The controls required in *Pt 17, Ch 2, 2.10 Special arrangements in machinery spaces and, where necessary, other spaces 2.10.6* are to be located outside the space concerned, in a position where they will not be cut off in the event of fire in the space they serve. Such controls and the controls for any required fire-extinguishing system are to be situated at one control position or grouped in as few positions as possible. Such positions are to have a safe access from the open deck. *See also Pt 15, Ch 3, 4.5 Control of pumps 4.5.1* and *Pt 15, Ch 3, 4.9 Valves on deep tanks and their control arrangements 4.9.2*.

2.11 Arrangements for gaseous fuel for domestic purposes

2.11.1 Where gaseous fuel is used for domestic purposes, the arrangements for the storage, distribution and utilisation of the fuel is to be such that, having regard to the hazards of fire and explosion which the use of such fuel may entail, the safety of the service craft and the persons onboard is preserved. The installation is to be in accordance with recognised National or International Standards.

2.11.2 Storage lockers for gas cylinders are to be provided with:

(a) effective ventilation

(b) an outward-opening door accessible directly to the open deck; and

(c) gas-tight boundaries, including doors and other means of closing any openings therein, which form boundaries between such lockers and adjoining spaces.

2.11.3 Arrangements for storage on open deck will be specially considered.

2.12 Space heaters

2.12.1 Space heaters, if used, are to be fixed in position and so constructed as to reduce fire risks to a minimum. The design and location of these units is to be such that clothing, curtains or other similar materials cannot be scorched or set on fire by heat from the unit.

2.13 Fixed fire detection and fire-alarm systems

2.13.1 A fixed fire detection and fire-alarm system is to be installed in all Category ‘A' machinery spaces and is to comply with the requirements of *Pt 16, Ch 1, 2.8 Fire detection and fire alarm systems*.

2.13.2 In craft over 50 gross tons, where sleeping accommodation is provided on board, a fixed fire detection and fire-alarm system is to be installed in all stairways, service spaces, machinery spaces, control stations and accommodation spaces (except toilets, bathrooms, void spaces, etc.). The fixed fire detection and fire-alarm system is to be installed in accordance with *Pt 17, Ch 4, 2 Fixed fire detection and fire-alarm systems*.

2.14 Fire pumps and fire main system

2.14.1 **Application**:

(a) Every service craft is to be provided with a fire pump(s), fire mains, hydrants and hoses as required by this Chapter.

(b) For very small service craft, where it is not considered possible to fit a fire pump, the arrangements will be specially considered.

2.14.2 **Capacity of fire pumps**. The capacity of the fixed main fire pump(s) is not to be less than:

$$Q = \left(0,15\left(L_{\mathrm{R}}(B+D)\right)^{1/2} + 2,25\right)^2$$

but need not exceed 25m^3/hour

where

B = greatest moulded breadth of craft, in metres

D = moulded depth to bulkhead deck, in metres

L_{R} = Rule length of craft, as defined in *Pt 3, Ch 1, 6.2 Principal particulars 6.2.1*, in metres

Q = total capacity in m^3 /hours.

2.14.3 **Fire pumps**:

(a) In service craft of 150 tons gross or more, a minimum of one fixed power pump and one portable pump, complying with *Pt 17, Ch 2, 2.14 Fire pumps and fire main system 2.14.4*, are to be provided.

(b) For service craft of less than 150 tons gross, one portable pump or alternative as required by *Pt 17, Ch 2, 2.14 Fire pumps and fire main system 2.14.4*, is to be provided.

(c) Sanitary, ballast, bilge or general service pumps may be accepted as fire pumps, provided that they are not normally used for pumping oil, and that, if they are subject to occasional duty for the transfer or pumping of fuel oil, suitable changeover arrangements are fitted.

(d) In service craft classed for navigation in ice, the fire pump sea inlet valves are to be provided with ice clearing arrangements, *see Pt 1, Ch 2, 3.8 Other hull notations 3.8.1*.

(e) Relief valves are to be provided in conjunction with any fire pumps if the pump is capable of developing a pressure exceeding the design pressure of the water service pipes, hydrants and hoses. These valves are to be so placed and adjusted as to prevent excessive pressure in any part of the fire main system.

(f) Where centrifugal pumps are provided in order to comply with this Section, a non-return valve is to be fitted in the pipe connecting each pump to the fire main.

2.14.4 **Portable fire pumps**

(a) Except for electric pumps, which will be specially considered, portable fire pumps are to comply with the following:

(i) The pump is to be self priming.

(ii) The suction head in operation is not to exceed 4,5 m.

(iii) The portable fire pump is to be fitted with a length of discharge hose and nozzle capable of maintaining a pressure sufficient to produce a jet throw of at least 12 m, or that required to enable a jet of water to be directed on any part of the engine room or the exterior boundary of the engine room and casing, whichever is the greater. The jet throw required need not exceed the length of the craft.

(iv) The pump set is to have its own fuel tank of sufficient capacity to operate the pump for three hours.

(v) Details of the fuel type and storage location are to be submitted. If the fuel type has a flashpoint below 60ºC, further consideration will be given to the fire safety aspects.

(vi) The pump set is to be stored in a secure, safe and enclosed space, accessible from open deck and clear of the Category ‘A' machinery space.

(vii) The pump set is to be easily moved and operated by two persons and be readily available for immediate use.

(viii) Arrangements are to be provided to secure the pump at its anticipated operating position(s).

(ix) The overboard suction hose is to be non-collapsible and of sufficient length to cater for the craft's motion under all operational conditions. A suitable strainer is to be fitted at the inlet end of the hose.

(x) Any diesel-driven power source for the pump is to be capable of being readily started in its cold condition down to a temperature of 0ºC by hand (manual) cranking.

(b) If it is not possible to comply with the requirements of *Pt 17, Ch 2, 2.14 Fire pumps and fire main system 2.14.4*, an additional fixed fire pump will be required, which is to comply with the following:

(i) The pump, its source of power and sea connection are to be located in accessible positions outside the Category ‘A' machinery space, or in a different space to the main fire pump, if the main fire pump is located outside the Category ‘A' machinery space. In the case of craft defined in *Pt 17, Ch 2, 2.14 Fire pumps and fire main system 2.14.3.(b)*, the pump may be situated in the Category ‘A' machinery space, if so desired.

(ii) The sea valve is to be capable of being operated from a position near the pump.

(iii) The space where the fire pump prime mover is located is to be illuminated from the emergency source of electrical power, except for craft defined in *Pt 17, Ch 2, 2.14 Fire pumps and fire main system 2.14.3.(b)*, and is to be well ventilated.

(iv) If the pump is required to supply water for a fixed fire-extinguishing system in the space where the main fire pumps are situated, it is to be capable of simultaneously supplying water to this system and the fire main at the required rates.

(v) The pump may also be used for other suitable purposes, subject to approval in each case.

(vi) The pressure and quantity of water delivered by the pump is to be sufficient to produce a jet of water at any nozzle of not less than 12 m.

(vii) In the case of craft defined in *Pt 17, Ch 2, 2.14 Fire pumps and fire main system 2.14.3.(b)*, a fire main, hydrants and hoses are to be installed in accordance with *Pt 17, Ch 2, 2.14 Fire pumps and fire main system 2.14.5*

(c) Means to illuminate the stowage area of the portable pump and its necessary areas of operation are to be provided from the emergency source of electrical power.

(d) If preferred, a pump complying with *Pt 17, Ch 2, 2.14 Fire pumps and fire main system 2.14.4.(b)* may be fitted instead of a portable pump complying with *Pt 17, Ch 2, 2.14 Fire pumps and fire main system 2.14.4*.

2.14.5 **Fire main**:

(a) The diameter of the fire main is to be based on the required capacity of the fixed main fire pump(s). The diameter of the water service pipes are to be sufficient to ensure an adequate supply of water for the operation of at least one fire-hose.

(b) The wash deck line may be used as a fire main provided that the requirements of this Section are satisfied.

(c) All exposed water pipes for fire-extinguishing are to be provided with drain valves for use in frosty weather. The valves are to be located where they will not be damaged by cargo.

2.14.6 **Pressure in the fire main**. When the fixed main fire pump, or the fire pump described in *Pt 17, Ch 2, 2.14 Fire pumps and fire main system 2.14.4.(b)*, is delivering the quantity of water required by *Pt 17, Ch 2, 2.14 Fire pumps and fire main system 2.14.2* through the fire main, fire hoses and nozzles, the pressure maintained at any hydrant is to be sufficient to produce a jet throw at any nozzle of not less than 12 m.

2.14.7 **Number and position of hydrants**. The number and position of the hydrants are to be such that at least one jet of water is to reach any part normally accessible to the crew while the service craft is being navigated and any part of any cargo space when empty. Furthermore, such hydrants are to be positioned near the accesses to the protected spaces. At least one hydrant is to be provided in each machinery space.

2.14.8 **Pipes and hydrants**:

(a) Materials readily rendered ineffective by heat are not to be used for fire mains. Where steel pipes are used, they are to be galvanised internally and externally. Cast iron pipes are not acceptable. The pipes and hydrants are to be so placed that the fire-hoses may be easily coupled to them. The arrangements of pipes and hydrants are to be such as to avoid the possibility of freezing. In service craft where deck cargo may be carried, the positions of the hydrants are to be such that they are always readily accessible and the pipes are to be arranged, as far as practicable, to avoid risk of damage by such cargo. Unless one hose and nozzle is provided for each hydrant in the service craft, there is to be complete interchangeability of hose couplings and nozzles.

(b) A valve is to be fitted at each fire hydrant so that any fire-hose may be removed while the fire pumps are at work.

(c) Where an additional fixed fire pump is fitted in accordance with *Pt 17, Ch 2, 2.14 Fire pumps and fire main system 2.14.4.(b)* or *Pt 17, Ch 2, 2.14 Fire pumps and fire main system 2.14.4.(d)*:

   (i) An isolating valve is to be fitted in the fire main so that all the hydrants in the service craft, except those in the Category ‘A' machinery space containing the main fire pump, can be supplied with water by the additional fixed fire pump. The isolating valve is to be located in an easily accessible and tenable position outside the Category ‘A' machinery space; and

   (ii) The fire main is not to re-enter the machinery space downstream of the isolating valve.

2.14.9 **Fire-hoses**:

(a) Fire-hoses are to be of approved non-perishable material. The hoses are to be sufficient in length to project a jet of water to any of the spaces in which they may be required to be used. Their length, in general, is not to exceed 18 m. Each hose is to be provided with a nozzle and the necessary couplings. Fire-hoses, together with any necessary fittings and tools, are to be kept ready for use in conspicuous positions near the water service hydrants or connections.

(b) The number of fire-hoses to be provided, each complete with couplings and nozzles, is to be one for each 15 m length of the service craft, or part thereof, but need not exceed the number of hydrants provided. This number does not include any hoses required in any engine room. If necessary, the number of hoses is to be increased so as to ensure that hoses in sufficient numbers are available and accessible at all times.

2.14.10 **Nozzles**:

(a) For the purpose of this Chapter, standard nozzle sizes are to be 12 mm, 16 mm or 19 mm, or as near thereto as possible, so as to make full use of the maximum discharge capacity of the fire pump(s).

(b) For accommodation and service spaces, the nozzle size need not exceed 12 mm.

(c) The size of nozzles intended for use in conjunction with a portable fire pump need not exceed 12 mm.

(d) All nozzles are to be of an approved dual purpose type (i.e. spray/jet type) incorporating a shut-off.

2.15 Fire-extinguishing arrangements in Category ‘A' machinery spaces

2.15.1 Except where provided for in *Pt 17, Ch 2, 2.15 Fire-extinguishing arrangements in Category ‘A' machinery spaces 2.15.2*, Category ‘A' machinery spaces are to be provided with:

(a) one of the fixed fire-extinguishing systems given in *Pt 17, Ch 4, 3 Fixed fire-extinguishing systems in machinery spaces*; and

(b) at least two portable foam extinguishers or equivalent, *see Pt 17, Ch 4, 6.3 Capacity 6.3.2*. Where internal combustion machinery is installed, an additional portable extinguisher is to be provided for every 375 kW of power output, but the total number of such additional extinguishers need not exceed five.

2.15.2 Where the size of the machinery space precludes access under normal operating conditions, provision is to be made such that a manually-released extinguishing medium, of a type allowed in *Pt 17, Ch 4 System and Equipment Specifications*, can be remotely discharged into the space. Such arrangements may utilize a portable extinguisher of adequate size. Details of the arrangements with supporting calculations are to be submitted for approval.

2.16 Fire-extinguishing appliances in other machinery spaces

2.16.1 Where a fire hazard exists in any machinery space for which no specific provisions for fire-extinguishing appliances are prescribed in *Pt 17, Ch 2, 2.15 Fire-extinguishing arrangements in Category ‘A' machinery spaces* and *Pt 17, Ch 2, 2.17 Machinery spaces in craft which are constructed mainly or wholly of alternative forms of construction*, there is to be provided in, or adjacent to, that space a satisfactory number of approved portable fire-extinguishers or other approved means of fire-extinction.

2.17 Machinery spaces in craft which are constructed mainly or wholly of alternative forms of construction

2.17.1 Machinery spaces in craft which are constructed mainly or wholly with alternative forms of construction that contain internal combustion machinery, are to comply with the fire-extinguishing requirements for Category ‘A' machinery spaces, *see Pt 17, Ch 2, 2.15 Fire-extinguishing arrangements in Category ‘A' machinery spaces 2.15.1*.

2.18 Fixed fire-extinguishing systems not required by this Chapter

2.18.1 Where a fixed fire-extinguishing system not required by this Chapter is installed, the arrangement is to comply with the relevant requirements of this Chapter.

2.19 Portable fire-extinguishers

2.19.1 All portable fire-extinguishers are to comply with the requirements of *Pt 17, Ch 4, 6 Fire-extinguishers (portable and non-portable)*.

2.19.2 The portable fire-extinguishers are to be stowed in readily accessible positions.

2.19.3 One of the portable fire-extinguishers intended for use in any space is to be stowed near the entrance to that space.

2.19.4 At least one portable fire-extinguisher is to be located so that it can easily be reached from the main steering position of the craft.

2.19.5 Accommodation spaces, service spaces and control stations are to be provided with a sufficient number of portable fire-extinguishers to ensure that at least one extinguisher will be readily available for use in every compartment.

2.19.6 Where cooking facilities are provided a portable fire-extinguisher of a type appropriate to the energy source used is to be located in a position readily accessible for use in the event of a fire.

2.20 Fire blanket

2.20.1 A fire blanket is to be installed in all galleys.

2.21 Protection of paint lockers and flammable liquid lockers

2.21.1 Paint lockers and flammable liquid lockers with a deck area 4 m^2 or over are to be provided with a fixed fire-extinguishing system enabling the crew to extinguish a fire without entering the space. One of the following systems is to be provided:

- A carbon dioxide system designed for 40 per cent of the gross volume of the space.
- A dry powder system designed to discharge 0,5 kg powder per cubic metre of gross volume of the space.
- A water spray system designed to give a coverage of 5 litres per square metre of deck area per minute. Water spray systems may be connected to the fire main.

2.21.2 Consideration will be given to the acceptance of other arrangements which provide equivalent protection.

2.21.3 Lockers having a deck area of less than 4 m^2 may be protected by carbon dioxide or dry powder portable extinguishers located near the entrance to the locker.

2.22 Arrangements where deep-fat cooking equipment is installed

2.22.1 Where deep-fat cooking equipment is installed in high speed craft, all installations are to be fitted with:

(a) an automatic or manual fixed extinguishing system type approved in accordance with ISO 15371, *Ships and marine technology-Fire extinguishing systems for protection of galley deep-fat cooking equipment-Fire tests*, or an acceptable alternative National or International Standard, for protection of the deep-fat cooking equipment;
(b) a primary and back up thermostat with an alarm to alert the operator in the event of failure of either thermostat;
(c) means to automatically shut off the deep-fat cooking equipment electrical power upon activation of the fire-extinguishing system;
(d) an alarm for indicating operation of the fire-extinguishing system in the galley where the equipment is installed; and
(e) controls for manual operation of the fire-extinguishing system which are clearly labelled for ready use by the crew.

Control and electrical engineering arrangements are to be in accordance with the requirements of *Pt 16, Ch 1 Control Engineering Systems* and *Pt 16, Ch 2 Electrical Engineering*, as applicable.

2.23 Helicopter decks

2.23.1 The requirements of *IMO Resolution A.855(20) – Standards for On-Board Helicopter Facilities – (Adopted on 27 November 1997)* are to be complied with having due regard to the hazards involved.

2.23.2 If a helicopter hangar is not provided and if two fireman's outfits are supplied as per *Pt 17, Ch 2, 2.24 Fireman's outfit 2.24.1*, then the fireman's outfits required by *IMO Resolution A.855(20) – Standards for On-Board Helicopter Facilities – (Adopted on 27 November 1997)* need not be provided.

2.24 Fireman's outfit

2.24.1 All service craft of 350 gross tons or more and having enclosed spaces which are normally accessible, are to carry at least two fireman's outfits complying with the requirements of *Pt 17, Ch 4, 4 Fireman's outfits*.

2.25 Fire-control plans

2.25.1 Fire control plans are to meet the requirements of *Pt 17, Ch 4, 5 Fire-control plans*.

Section 1
General requirements

1.1 Application

1.1.1 The requirements of this Chapter apply to yachts with an overall length, L_{OA} (as defined in *Pt 3, Ch 1, 6.2 Principal particulars 6.2.4*) of 24 m or greater built in accordance with the Rules.

1.1.2 Where yachts incorporate fire hazards not covered in this Part, appropriate fire protection, detection and extinction arrangements are to be provided. Details are to be submitted for approval.

1.1.3 For yachts with an overall length of 24 m or more, and less than 500 gt, the fire safety measures are to comply with *Pt 17, Ch 3, 2 Fire safety measures for yachts of overall length greater than 24 m but less than 500 gt*.

1.1.4 For yachts 500 gt or more, the fire safety measures are to comply with *Pt 17, Ch 3, 3 Fire safety measures for yachts 500 gt or more* .

Section 2
Fire safety measures for yachts of overall length greater than 24 m but less than 500 gt

2.1 General

2.1.1 *Table 3.2.1 General fire protection, detection and extinction requirements* is a guide to the major requirements of this Section. The Table is intended as a quick reference to the requirements and is not to be used in isolation when designing the fire safety arrangements.

Table 3.2.1 General fire protection, detection and extinction requirements

Form of construction, *see Pt 17, Ch 3, 2.2 Forms of construction – Structure*	Steel or equivalent, or alternative forms of construction may be accepted subject to requirements
Passive fire protection, *see Pt 17, Ch 3, 2.3 Forms of construction – Fire divisions*	• Category ‘A’ machinery spaces ‘A-30’/‘A-0’ • Galleys: ‘B-15’ where significant fire risk • Bulkheads in escape route corridors greater than 7 m in length: ‘B-0’ • Stairway enclosures: ‘B-0’
Means of escape, *see* 2.7	
• Category ‘A’ machinery spaces	2
• Accommodation, etc.	2

Fixed fire detection system, *see Pt 17, Ch 3, 2.13 Fixed fire detection and fire-alarm systems*	• Fitted in machinery spaces • Fitted in service spaces, control stations and accommodation spaces
Fire pumps, *see Pt 17, Ch 3, 2.14 Fire pumps and fire main system*	1 fixed power pump + 1 portable pump
Fire extinguishing arrangements in Category 'A' machinery spaces, *see Pt 17, Ch 3, 2.15 Fire-extinguishing arrangements in machinery spaces*	• A fixed fire-extinguishing system • A minimum of 2 and maximum of 5 portable foam extinguishers or equivalent
Portable fire-extinguishers in accommodation, *see Pt 17, Ch 3, 2.18 Portable fire-extinguishers*	At least 3
Automatic sprinkler system or equivalent, *see Pt 17, Ch 3, 2.16 Automatic sprinkler, fire detection and fire-alarm system*	Fitted in yachts > 350 gross tons

2.2 Forms of construction – Structure

2.2.1 The hull, superstructure, structural bulkheads, decks and deckhouses may be constructed of steel, other equivalent material, *see Pt 17, Ch 1, 2.1 Materials 2.1.2* or be of alternative forms of construction, *see Pt 17, Ch 1, 2.1 Materials 2.1.3*.

2.2.2 The structure in way of Category 'A' machinery spaces, galleys containing appliances of significant fire risk, *see Pt 17, Ch 3, 2.4 Structural fire protection 2.4.2*, and other high risk areas is to be protected such that the material by itself or due to insulation provided can maintain its required strength at the end of 30 minutes exposure to the standard fire test.

2.2.3 Details of the method of construction, supported by calculations and/or fire test data, demonstrating compliance with *Pt 17, Ch 3, 2.2 Forms of construction – Structure 2.2.2* are to be submitted.

2.2.4 For aluminium alloy structures, the insulation is to be such that the temperature of the structural core does not rise more than 200°C above the ambient temperature at any time during the specified fire exposure.

2.2.5 For composite structures, the insulation is to be such that the temperature of the laminate does not rise more than the minimum temperature of deflection under load of the resin at any time during the specified fire exposure. The temperature of deflection under load is to be determined as in *Ch 14, 3.7 Tests for specific materials*of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

2.2.6 For structures in contact with sea-water, the required insulation should extend to at least 300 mm below the lightest waterline, *see also Pt 17, Ch 3, 2.6 Surface of insulation 2.6.1*.

2.3 Forms of construction – Fire divisions

2.3.1 Fire divisions required by *Pt 17, Ch 3, 2.4 Structural fire protection* are to be constructed in accordance with the remaining paragraphs of this sub-Section.

2.3.2 Fire divisions using steel equivalent, or alternative forms of construction may be accepted if it can be demonstrated that the material by itself, or due to insulation provided, has the fire resistance properties equivalent to 'A' or 'B' Class divisions.

2.3.3 Insulation required by *Pt 17, Ch 3, 2.3 Forms of construction – Fire divisions 2.3.2* is to be such that the temperature of the structural core does not rise above the point at which the structure would begin to lose its strength at any time during the applicable exposure to the standard fire test. For 'A' Class divisions, the applicable exposure is 60 minutes, and for 'B' Class divisions, the applicable exposure is 30 minutes.

2.3.4 For aluminium alloy structures, the insulation is to be such that the temperature of the structural core does not rise more than 200°C above the ambient temperature at any time during the applicable fire exposure.

2.3.5 For composite structures, the insulation is to be such that the temperature of the laminate does not rise more than the minimum temperature of deflection under load of the resin at any time during the applicable fire exposure. The temperature of deflection under load is to be determined as in *Ch 14, 3.7 Tests for specific materials* of the Rules for Materials.

2.4 Structural fire protection

2.4.1 Category ‘A' machinery spaces, spaces containing vehicles or craft with fuel in their tanks, or lockers storing such fuels, are to be enclosed by ‘A-30' Class divisions where adjacent to accommodation or service spaces, control positions or each other, and ‘A-0' Class divisions elsewhere.

2.4.2 Galleys are to be enclosed by ‘B-15' Class divisions, unless the cooking appliances contained therein have an insignificant fire risk.

(a) For the purposes of this Chapter, coffee automats, toasters, dishwashers, microwave ovens, water boilers and similar appliances each with a maximum power of 5 kW may be regarded as having an insignificant fire risk. Electrically-heated cooking plates and hot plates for keeping food warm, each of them having a maximum power of 2 kW and a surface temperature not above 150°C may also be regarded as having insignificant fire risk. If spaces containing this equipment are lockable, then means of cutting-off the power to the space are to comply with *Pt 16, Ch 2, 17.6 Fire safety stops 17.6.7*.

(b) Other equipment such as fat fryers, open flame cookers, etc. would be regarded as having a significant fire risk.

2.4.3 Where forming escape routes, corridor bulkheads and ceilings may be constructed of combustible materials provided they have a non-combustible core such that the ‘B-0' Class standard fire test criteria are met.

2.4.4 Stairways connecting spaces below the main deck to the deck above are to be protected at one level by at least ‘B-0' Class divisions and self-closing doors.

2.4.5 Lift and dumbwaiter trunks are to be enclosed by at least ‘B-0' Class divisions and self-closing doors.

2.4.6 Openings in ‘A' and ‘B' Class divisions are to be provided with permanently attached means of closing that are to be at least as effective for resisting fires as the divisions in which they are fitted.

2.4.7 Interior stairways serving machinery spaces, accommodation spaces, service spaces or control stations are to be of steel, or other equivalent material.

2.4.8 Where ‘A' Class divisions are penetrated for the passage of electric cables, pipes, trunks, ducts, etc. or for girders, beams or other structural members, arrangements are to be made to ensure that the fire resistance is not impaired.

2.4.9 Where ‘B' Class divisions are penetrated for the passage of electric cables, pipes, trunks, ducts, etc. or for the fitting of ventilation terminals, lighting fixtures and similar devices, arrangements are to be made to ensure that the fire resistance is not impaired.

2.4.10 Where the structure or ‘A' Class divisions are required to be insulated, it is to be ensured that the heat from a fire is not transmitted through the intersections and terminal points of the divisions or penetrations to uninsulated boundaries. Where the insulation installed does not achieve this, arrangements are to be made to prevent this heat transmission by insulating the horizontal and vertical boundaries or penetrations for a distance of 450 mm.

2.5 Materials

2.5.1 Except in refrigerated compartments of service spaces, all insulation other than fire insulation is to be of not-readily ignitable type. Fire insulation is to be of the non-combustible type

2.5.2 Pipes penetrating ‘A' or ‘B' Class divisions are to be of approved materials having regard to the temperature such divisions are required to withstand.

2.5.3 Pipes conveying oil or combustible liquids through accommodation and service spaces are to be of approved materials having regard to the fire risk.

2.5.4 Materials readily rendered ineffective by heat are not to be used for overboard scuppers, sanitary discharges, and other outlets which are close to the waterline and where the failure of the material in the event of fire would give rise to danger of flooding.

2.5.5 Primary deck coverings within accommodation spaces, service spaces and control stations are to be of a type that will not readily ignite, or give rise to toxic or explosive hazards at elevated temperatures. Reference is also to be made to the IMO FTP Code, Annex 1, *Part 2 - Smoke and Toxicity Test* and *Part 6 - Test for Primary Deck Coverings*.

2.5.6 Vapour barriers and adhesives used in conjunction with insulation, as well as insulation of pipe fittings for cold service systems need not be non-combustible, but they are to be kept to the minimum quantity practicable and their exposed surfaces are to have low flame spread characteristics.

2.5.7 All waste receptacles are to be constructed of non-combustible materials with no openings in the sides or bottom.

2.6 Surface of insulation

2.6.1 In spaces where penetration of oil products is possible, the surface of insulation is to be impervious to oil or oil vapours. Insulation boundaries are to be arranged to avoid immersion in oil spillages.

2.7 Means of escape

2.7.1 Stairways, ladders and corridors serving all spaces normally accessible are to be arranged so as to provide ready means of escape to a deck from which embarkation into survival craft may be effected.

2.7.2 Where reasonable and practicable, and having regard to the number of personnel involved and size of space, at least two means of escape, as widely separated as possible, are to be provided from each section of accommodation and service spaces and control stations:

(a) The normal means of access to the accommodation and service spaces below the open deck is to be arranged so that it is possible to reach the open deck without passing through intervening spaces containing a possible source of fire.

(b) Where accommodation arrangements are such that access to compartments is through another compartment, as is often the case with an Owner's suite, a second means of escape is to be provided. The second escape route is to be as remote as possible from the main escape route.

(c) This second means of escape may be through portholes, or hatches of adequate size, leading to the open deck.

(d) No dead-end corridors having a length of more than 7 m will be accepted. A 'dead-end corridor' is a corridor or part of a corridor from which there is only one escape route.

2.7.3 At least one of the means of escape from each space referred to in *Pt 17, Ch 3, 2.7 Means of escape 2.7.2* is to be enclosed by ‘B-0' Class divisions, unless it gives access directly to the open decks from the space.

2.7.4 At least two means of escape are to be provided from machinery spaces, except where the small size of the machinery space makes it impracticable. Escape is to be by steel ladders that are as widely separated as possible.

2.7.5 Lifts are not considered as forming a means of escape.

2.8 Ventilation systems

2.8.1 Ventilation fans are to be capable of being stopped, and main inlets and outlets of ventilation systems closed, from outside the spaces being served, *see Pt 16, Ch 2, 17.6 Fire safety stops*.

2.8.2 Ventilation ducts for Category ‘A' machinery spaces, exhaust ducts for galleys of significant fire risk, spaces containing vehicles or craft with fuel in their tanks, or lockers storing such fuels, are not to pass through accommodation spaces, service spaces or control stations unless the ducts are constructed of steel and arranged to preserve the integrity of the division.

2.8.3 Ventilation ducts for accommodation spaces, service spaces or control stations are not to pass through Category ‘A' machinery spaces, spaces containing vehicles or craft with fuel in their tanks, or lockers storing such fuels, unless the ducts are constructed of steel and arranged to preserve the integrity of the division.

2.8.4 Store-rooms containing highly flammable products are to be provided with ventilation arrangements that are separate from other ventilation systems. Ventilation is to be arranged to prevent the build up of flammable vapours at high and low levels. The inlets and outlets of ventilators are to be positioned so that they do not draw from or vent into an area which would cause undue hazard, and are to be fitted with spark arresters.

2.8.5 Ventilation systems serving Category ‘A' machinery spaces are to be independent of systems serving other spaces.

2.8.6 All enclosed spaces containing free-standing fuel tanks are to be ventilated independently of systems serving other spaces.

2.8.7 Ventilation is to be provided to prevent the accumulation of dangerous concentrations of flammable gas which may be emitted from batteries. The requirements of *Pt 16, Ch 2, 12.5 Thermal management and ventilation* are to be complied with.

2.8.8 Ventilation openings may be fitted in and under the lower parts of cabin and public space doors in corridor bulkheads. The total net area of any such openings is not to exceed 0,05 m^2. Bridging ducts are not allowed in fire divisions.

2.8.9 For spaces containing vehicles or craft with fuel in their tanks or lockers storing such fuels, *see Pt 17, Ch 3, 2.20 Protection of spaces containing vehicles or craft with fuel in their tanks or lockers storing such fuels 2.20.1.(d)*. For additional requirements for the ventilation of domestic gaseous fuel, *see Pt 17, Ch 3, 2.11 Arrangements for gaseous fuel for domestic purposes*.

2.9 Fuel arrangements

2.9.1 In yachts in which fuel oil is used, the arrangements for the storage, distribution and utilisation of the fuel oil are to be such as to ensure the safety of the yacht and persons on board. For details, *see Pt 15, Ch 3 Machinery Piping Systems*.

2.9.2 Fuel oil tanks situated within the boundaries of Category ‘A' machinery spaces are not to contain fuel oil having a flashpoint of less than 60°C.

2.9.3 Fuel oil, lubricating oil and other flammable oils are not to be carried in fore peak tanks.

2.10 Special arrangements in Category 'A' machinery spaces and, where necessary, other machinery spaces

2.10.1 Openings are to be provided with closing appliances constructed so as to maintain the fire integrity of the machinery space boundaries.

2.10.2 The type of equipment installed and the layout of the yacht are to take account of the risk and spread of fire. Special attention is to be paid to the surroundings of open flame devices, hot areas and main and auxiliary machinery, oil and fuel overflows, and uncovered oil and fuel pipes.

2.10.3 Fuel filling, storage, venting and supply systems are to be installed so as to minimise the risk of fire and explosion.

2.10.4 Machinery components and accessories that require frequent maintenance and inspection are to be readily accessible.

2.10.5 Windows are not to be fitted in machinery space boundaries. This does not preclude the use of glass in control rooms within the machinery spaces.

2.10.6 Means of control are to be provided for:

(a) closure of openings which normally allow exhaust ventilation, and closure of ventilator dampers;
(b) permitting the release of smoke;
(c) stopping ventilating fans; and
(d) stopping forced and induced draught fans, fuel oil transfer pumps, fuel oil unit pumps and other similar fuel pumps.

2.10.7 The controls required in *Pt 17, Ch 3, 2.10 Special arrangements in Category 'A' machinery spaces and, where necessary, other machinery spaces 2.10.6* are to be located outside the space concerned, in a position where they will not be cut off in the event of fire in the space they serve. Such controls and the controls for any required fire-extinguishing system are to be situated at one control position or grouped in as few positions as possible. Such positions are to have a safe access from the open deck. *See also Pt 15, Ch 3, 4.5 Control of pumps 4.5.1* and *Pt 15, Ch 3, 4.9 Valves on deep tanks and their control arrangements 4.9.2*.

2.11 Arrangements for gaseous fuel for domestic purposes

2.11.1 Where gaseous fuel is used for domestic purposes, the arrangements for the storage, distribution and utilisation of the fuel is to be such that, having regard to the hazards of fire and explosion which the use of such fuel may entail, the safety of the yacht and the persons onboard is preserved. The installation is to be in accordance with recognised National or International Standards.

2.11.2 Storage lockers for gas cylinders are to be provided with:

(a) effective ventilation:
(b) an outward-opening door accessible directly to the open deck; and
(c) gas-tight boundaries, including doors and other means of closing any openings therein, which form boundaries between such lockers and adjoining spaces.

2.11.3 Arrangements for storage on open deck will be specially considered.

2.12 Space heaters

2.12.1 Space heaters, if used, are to be fixed in position and so constructed as to reduce fire risks to a minimum. The design and location of these units are to be such that clothing, curtains or other similar materials cannot be scorched or set on fire by heat from the unit.

2.13 Fixed fire detection and fire-alarm systems

2.13.1 A fixed fire detection and fire-alarm system are to be installed in all Category 'A' machinery spaces and are to comply with the requirements of *Pt 16, Ch 1, 2.8 Fire detection and fire alarm systems*.

2.13.2 A fixed fire detection and fire-alarm system are to be fitted in all stairways (including lift and dumbwaiter trunks), service spaces, control stations and accommodation spaces (except toilets, bathrooms, void spaces, etc.). The fixed fire detection and fire-alarm system are to be installed in accordance with *Pt 17, Ch 4, 2 Fixed fire detection and fire-alarm systems*.

2.13.3 All yachts at all times when at sea, or in port (except when out of service), are to be so equipped as to ensure that any initial fire-alarm is immediately received by a responsible member of the crew.

2.13.4 A special alarm, operated from the navigating bridge or fire-control station, is to be fitted to summon the crew.

2.14 Fire pumps and fire main system

2.14.1 **Application**. Every yacht is to be provided with a fire pump(s), fire mains, hydrants and hoses as required by this Section.

2.14.2 **Capacity of fire pumps**. The capacity of the fixed main fire pump(s) is not to be less than:

$$Q = \left(0,15\left(L_{\mathrm{R}}(B + D)\right)^{1/2} + 2,25\right)^2$$

$$\textit{butneednotexceed}\ 25\ \mathrm{m}^3/\mathrm{hour}$$

where

B = greatest moulded breadth of yacht, in metres

D = moulded depth to bulkhead deck, in metres

L_{R} = Rule length of yacht, as defined in *Pt 3, Ch 1, 6.2 Principal particulars 6.2.1*, in metres

Q = total capacity in m^3 /hour.

2.14.3 **Fire pumps**:

(a) A minimum of one fixed power pump and one portable pump or alternative, complying with *Pt 17, Ch 3, 2.14 Fire pumps and fire main system 2.14.4*, are to be provided.

(b) Sanitary, ballast, bilge or general service pumps may be accepted as fire pumps, provided that they are not normally used for pumping oil, and that, if they are subject to occasional duty for the transfer or pumping of fuel oil, suitable changeover arrangements are fitted.

(c) In yachts classed for navigation in ice, the fire pump sea inlet valves are to be provided with ice clearing arrangements, *see Pt 1, Ch 2, 3.8 Other hull notations 3.8.1*.

(d) Relief valves are to be provided in conjunction with any fire pump if the pump is capable of developing a pressure exceeding the design pressure of the water service pipes, hydrants and hoses. These valves are to be so placed and adjusted as to prevent excessive pressure in any part of the fire main system.

(e) Where centrifugal pumps are provided in order to comply with this Section, a non-return valve is to be fitted in the pipe connecting each pump to the fire main.

2.14.4 **Portable fire pumps**:

(a) Except for electric pumps, which will be specially considered, portable fire pumps are to comply with the following:

  (i) The pump is to be self priming.

  (ii) The suction head in operation is not to exceed 4,5 m.

  (iii) The portable fire pump is to be fitted with a length of discharge hose and nozzle capable of maintaining a pressure sufficient to produce a jet throw of at least 12 m or that required to enable a jet of water to be directed on any part of the engine room or the exterior boundary of the engine room and casing, whichever is the greater.

  (iv) The pump set is to have its own fuel tank of sufficient capacity to operate the pump for three hours.

  (v) Details of the fuel type and storage location are to be submitted. If the fuel type has a flashpoint below 60°C, further consideration to the fire safety aspects will be given.

  (vi) The pump set is to be stored in a secure, safe and enclosed space, accessible from open deck and clear of the Category 'A' machinery space.

(vii) The pump set is to be easily moved and operated by two persons and be readily available for immediate use.

(viii) Arrangements are to be provided to secure the pump at its anticipated operating position(s).

(ix) The overboard suction hose is to be non-collapsible and of sufficient length to cater for the yacht's motion under all operational conditions. A suitable strainer is to be fitted at the inlet end of the hose.

(x) Any diesel driven power source for the pump is to be capable of being readily started in its cold condition down to a temperature of 0°C by hand (manual) cranking.

(b) If it is not possible to comply with the requirements of *Pt 17, Ch 3, 2.14 Fire pumps and fire main system 2.14.4*, an additional fixed fire pump will be required, which is to comply with the following:

(i) The pump, its source of power and sea connection are to be located in accessible positions outside the Category ‘A' machinery space, or in a different space to the main fire pump, if the main fire pump is located outside the Category ‘A' machinery space.

(ii) The sea valve is to be capable of being operated from a position near the pump.

(iii) The room where the fire pump prime mover is located is to be illuminated from the emergency source of electrical power and is to be well ventilated.

(iv) If the pump is required to supply water for a fixed fire-extinguishing system in the space where the main fire pumps are situated, it is to be capable of simultaneously supplying water to this system and the fire main at the required rates.

(v) The pump may also be used for other suitable purposes, subject to approval in each case.

(vi) The pressure and quantity of water delivered by the pump is to be sufficient to produce a jet of water at any nozzle of not less than 12 m.

(c) Means to illuminate the stowage area of the portable pump and its necessary areas of operation are to be provided from the emergency source of electrical power.

(d) If preferred, a pump complying with *Pt 17, Ch 3, 2.14 Fire pumps and fire main system 2.14.4.(b)* may be fitted instead of a portable pump complying with *Pt 17, Ch 2, 2.14 Fire pumps and fire main system 2.14.4*, *see also Pt 17, Ch 3, 2.14 Fire pumps and fire main system 2.14.8.(c)*.

2.14.5 **Fire main**:

(a) The diameter of the fire main is to be based on the required capacity of the fixed main fire pump(s). The diameter of the water service pipes are to be sufficient to ensure an adequate supply of water for the operation of at least one fire-hose.

(b) The wash deck line may be used as a fire main provided that the requirements of this Section are satisfied.

(c) All exposed water pipes for fire-extinguishing are to be provided with drain valves for use in frosty weather. The valves are to be located where they will not be damaged.

2.14.6 **Pressure in the fire main**. When the fixed main fire pump, or the fire pump described in *Pt 17, Ch 3, 2.14 Fire pumps and fire main system 2.14.4.(b)*, is delivering the quantity of water required by *Pt 17, Ch 3, 2.14 Fire pumps and fire main system 2.14.2* through the fire main, fire-hoses and nozzles, the pressure maintained at any hydrant is to be sufficient to produce a jet throw at any nozzle of not less than 12 m.

2.14.7 **Number and position of hydrants**. The number and position of the hydrants are to be such that at least one jet of water is to reach any part normally accessible to any person while the yacht is being navigated. Furthermore, such hydrants are to be positioned near the accesses to the protected spaces. At least one hydrant is to be provided in each Category ‘A' machinery space.

2.14.8 **Pipes and hydrants**:

(a) Materials readily rendered ineffective by heat are not to be used for fire mains. For the use of aluminium alloy *see Pt 15, Ch 1, 10.1 General 10.1.4*. Where steel pipes are used, they are to be galvanised internally and externally. Cast iron pipes are not acceptable. The pipes and hydrants to be so placed that the fire-hoses may be easily coupled to them. The arrangement of pipes and hydrants is to be such as to avoid the possibility of freezing. Unless one hose and nozzle is provided for each hydrant in the yacht, there is to be complete interchangeability of hose couplings and nozzles.

(b) A valve is to be fitted at each fire hydrant so that any fire-hose may be removed while the fire pump is at work.

(c) Where an additional fixed fire pump is fitted in accordance with *Pt 17, Ch 3, 2.14 Fire pumps and fire main system 2.14.4.(b)* or *Pt 17, Ch 3, 2.14 Fire pumps and fire main system 2.14.4.(d)*:

(i) An isolating valve is to be fitted in the fire main so that all the hydrants in the yacht, except those in the Category ‘A' machinery space containing the main fire pump, can be supplied with water by the additional fixed fire pump. The isolating valve is to be located in an easily accessible and tenable position outside the Category ‘A' machinery space; and

(ii) the fire main is not to re-enter the machinery space downstream of the isolating valve.

2.14.9 **Fire-hoses**:

(a) Fire-hoses are to be of approved non-perishable material. The hoses are to be sufficient in length to project a jet of water to any of the spaces in which they may be required to be used. Their length, in general, is not to exceed 18 m. Each hose is to be provided with a nozzle and the necessary couplings. Fire-hoses, together with any necessary fittings and tools, are to be kept ready for use in conspicuous positions near the water service hydrants or connections.

(b) A minimum of three fire-hoses are to be provided, each complete with couplings and nozzles. These numbers do not include any hoses required in any engine room. If necessary, the number of hoses is to be increased so as to ensure that hoses in sufficient number are available and accessible at all times.

2.14.10 **Nozzles**:

(a) For the purpose of this Chapter, standard nozzle sizes are to be 12 mm, 16 mm or 19 mm, or as near thereto as possible, so as to make full use of the maximum discharge capacity of the fire pump or pumps.

(b) For accommodation and service spaces, the nozzle size need not exceed 12 mm.

(c) The size of nozzles intended for use in conjunction with a portable fire pump need not exceed 12 mm.

(d) All nozzles are to be of an approved dual purpose type (i.e. spray/jet type) incorporating a shut-off.

2.15 Fire-extinguishing arrangements in machinery spaces

2.15.1 **Category ‘A' machinery spaces** are to be provided with:

(a) One of the fixed fire-extinguishing system given in *Pt 17, Ch 4, 3 Fixed fire-extinguishing systems in machinery spaces*; and

(b) at least two portable foam extinguishers or equivalent, *see Pt 17, Ch 4, 6.3 Capacity 6.3.2*. Where internal combustion machinery is installed, an additional portable extinguisher is to be provided for every 375 kW of power output, but the total number of such additional extinguishers need not exceed five.

2.15.2 **Fire-extinguishing appliances in other machinery spaces**. Where a fire hazard exists in any machinery space for which no specific provisions for fire-extinguishing appliances are prescribed in *Pt 17, Ch 3, 2.15 Fire-extinguishing arrangements in machinery spaces 2.15.1* or *Pt 17, Ch 3, 2.15 Fire-extinguishing arrangements in machinery spaces 2.15.3* there is to be provided in or adjacent to that space, a satisfactory number of approved portable fire-extinguishers or other approved means of fire-extinction.

2.15.3 **Machinery spaces, other than Category ‘A', in yachts which are constructed mainly or wholly with alternative forms of construction.** In yachts that are constructed mainly or wholly with alternative forms of construction, machinery spaces, other than Category ‘A', containing internal combustion machinery, are to comply with the fire-extinguishing requirements for Category ‘A' machinery spaces, *see Pt 17, Ch 3, 2.15 Fire-extinguishing arrangements in machinery spaces 2.15.1*.

2.16 Automatic sprinkler, fire detection and fire-alarm system

2.16.1 A fixed automatic sprinkler must be fitted in yachts over 350 gross tons, fire detection and fire-alarm system, or equivalent system (e.g. watermist), are to be fitted in all stairways, service spaces, control stations and accommodation spaces, except in general, in spaces which afford no fire risk such as void spaces.

2.16.2 The arrangements are to be in accordance with *Pt 17, Ch 4, 1 Automatic sprinkler, fire detection and fire-alarm systems*, particular attention should be given to *Pt 17, Ch 4, 1.2 Wet pipe type 1.2.16* and *Pt 17, Ch 4, 1.2 Wet pipe type 1.2.17*.

2.17 Fixed fire-extinguishing systems not required by this Section

2.17.1 Where a fixed fire-extinguishing system not required by this Chapter is installed, the arrangement is to comply with the relevant requirements of this Chapter.

2.18 Portable fire-extinguishers

2.18.1 All portable fire-extinguishers are to comply with the requirements of *Pt 17, Ch 4, 6 Fire-extinguishers (portable and non-portable)*.

2.18.2 The portable fire-extinguishers are to be stowed in readily accessible positions.

2.18.3 One of the portable fire-extinguishers intended for use in any space is to be stowed near the entrance to that space.

2.18.4 At least one portable fire-extinguisher is to be located so that it can easily be reached from the main steering position of the yacht.

2.18.5 Accommodation spaces, service spaces and control stations are to be provided with a sufficient number of portable fire-extinguishers to ensure that at least one extinguisher will be readily available for use in every compartment. In any case, their number is to be not less than three.

2.18.6 Where cooking facilities are provided, a portable fire-extinguisher of a type appropriate to the energy source used is to be located in a position readily accessible for use in the event of a fire.

2.19 Fire blanket

2.19.1 A fire blanket is to be installed in all galleys.

2.20 Protection of spaces containing vehicles or craft with fuel in their tanks or lockers storing such fuels

2.20.1 Spaces containing vehicles or craft with fuel in their tanks, or lockers storing such fuels, are to be provided with the following:

(a) A fixed fire detection and fire-alarm system complying with the requirements of *Pt 16, Ch 1, 2.8 Fire detection and fire alarm systems*
(b) A manually-operated water spray deluge system having a water application rate of 5 litres per square metre of deck area per minute. Where the deck height does not exceed 2,5 m, an application rate of 3,5 litres per square metre of deck area per minute will be accepted. Adequate drainage of the protected spaces is to be provided generally in accordance with the requirements for vehicle or cargo spaces*, see Pt 3, Ch 4, 9.4 Scupper arrangements 9.4.4*. The drainage piping and connection for the space are to be non-combustible. Other fixed fire-extinguishing systems may be permitted, provided they are not less effective in controlling the type of fire likely to occur.
(c) At least two portable foam extinguishers or equivalent.
(d) An independent mechanical ventilation system, which is entirely separate from other ventilation systems, providing at least six air changes per hour. The ducted air is not to pass through other spaces, except as allowed under *Pt 17, Ch 3, 2.8 Ventilation systems 2.8.2*, or vent into areas where it could be drawn into accommodation areas or cause undue hazard.
(e) Electrical equipment of a safe type is to be provided, *see Pt 16, Ch 2, 14 Electrical equipment for use in explosive atmospheres*.
(f) Prominently displayed 'No Smoking' signs.
(g) ‘A-30' Class divisions where adjacent to Category ‘A' machinery spaces, accommodation or service spaces, or control positions and ‘A-0' Class divisions elsewhere.

2.20.2 Such spaces are not to give access to any space other than the fuel store or lockers for use within the space. Lockers storing fuel are to be accessed from an exterior location, unless the locker is within the space containing the vehicles or craft. Exceptionally, where the engine room escape cannot be routed elsewhere, it may exit into the space providing that:

(a) the connecting door is self-closing;
(b) no door hold back devices are fitted;
(c) an audible and visual alarm is fitted on the bridge to signify when the door is open; and
(d) a notice is posted at the door stating that the door is to remain closed and that the area beside the door is an escape route and is to be kept clear.

2.20.3 The requirements of *Pt 17, Ch 3, 2.9 Fuel arrangements* are to be complied with, as appropriate.

2.21 Protection of paint lockers and flammable liquid lockers

2.21.1 Paint lockers and flammable liquid lockers with a deck area of 4 m^2 or over, are to be provided with a fixed fire-extinguishing system enabling the crew to extinguish a fire without entering the space. One of the following systems is to be provided:

- A carbon dioxide system designed for 40 per cent of the gross volume of the space.
- A dry powder system designed to discharge 0,5 kg powder per cubic metre of gross volume of the space.
- A water spray system designed to give a coverage of 5 litres per square metre of deck area per minute. Water spray systems may be connected to the fire main.

2.21.2 Consideration will be given to the acceptance of other arrangements which provide equivalent protection.

2.21.3 Lockers having a deck area of less than 4 m^2 may be protected by carbon dioxide or dry powder portable extinguishers located near the entrance to the locker.

2.22 Helicopter decks

2.22.1 The requirements of *IMO Resolution A.855(20) – Standards for On-Board Helicopter Facilities – (Adopted on 27 November 1997)* are to be complied with having due regard to the hazards involved.

2.22.2 If a helicopter hangar is not provided and if two fireman's outfits are supplied as per *Pt 17, Ch 3, 2.23 Fireman's outfit 2.23.1*, then the fireman's outfits required by*IMO Resolution A.855(20) – Standards for On-Board Helicopter Facilities – (Adopted on 27 November 1997)* need not be provided.

2.23 Fireman's outfit

2.23.1 All yachts of 350 gross tons or more are to carry at least two fireman's outfits complying with the requirements of *Pt 17, Ch 4, 4 Fireman's outfits*.

2.24 Fire-control plans

2.24.1 Fire control plans are to meet the requirements of *Pt 17, Ch 4, 5 Fire-control plans*.

■ *Section 3*
Fire safety measures for yachts 500 gt or more

3.1 General

3.1.1 *Table 3.3.1 General fire protection, detection and extinction requirements* is a guide to the major requirements of this Section. The Table is intended as a quick reference to the requirements and is not to be used in isolation when designing the fire safety arrangements.

Table 3.3.1 General fire protection, detection and extinction requirements

Form of construction, *see Pt 17, Ch 3, 3.2 Forms of construction – Structure*	Steel or equivalent, or alternative forms of construction may be accepted subject to extensive insulation requirements
Passive fire protection, *see Pt 17, Ch 3, 3.3 Forms of construction – Fire divisions*	*See Table 3.3.2 Fire integrity of bulkheads separating adjacent spaces* and *Table 3.3.3 Fire integrity of decks separating adjacent spaces*
Means of escape, *see Pt 17, Ch 3, 3.15 Structural fire protection – Means of escape*:	
• Category ‘A’ machinery spaces	2
• Accommodation, etc.	2
Fixed fire detection system, *see Pt 17, Ch 3, 3.24 Fixed fire detection and fire-alarm systems*	• Fitted in machinery spaces • Fitted in service spaces, control stations and accommodation spaces
Fire pumps, *see Pt 17, Ch 3, 3.25 Fire pumps and fire main system*	• In general, 2 independent power pumps • For yachts of ≥ 4000 gross tons: 3 independent power pumps • A fire in any one compartment is not to put all the fire pumps out of action
International shore connection, *see Pt 17, Ch 3, 3.25 Fire pumps and fire main system 3.25.11*	At least 1

Fire extinguishing arrangements in Category ‘A’ machinery spaces, *see Pt 17, Ch 3, 3.26 Fire-extinguishing arrangements in spaces containing internal combustion machinery*. *See also Pt 17, Ch 3, 3.27 Fire-extinguishing arrangements in spaces containing fuel oil units* for fuel oil units	• A fixed fire extinguishing system • Portable air-foam equipment • 45 litre foam extinguisher • Portable foam extinguishers within 10 m walking distance
Portable fire-extinguishers in accommodation, *see Pt 17, Ch 3, 3.32 Portable fire-extinguishers*	Sufficient to ensure that at least one will be readily available in every compartment, but a minimum of five
Automatic sprinkler system or equivalent, *see Pt 17, Ch 3, 3.29 Automatic sprinkler, fire detection and fire-alarm system*	Fitted in all yachts
Fireman’s outfits, *see Pt 17, Ch 3, 3.38 Fireman's outfit*	At least 2

3.2 Forms of construction – Structure

3.2.1 The hull, superstructure, structural bulkheads, decks and deckhouses may be constructed of steel, other equivalent material, *see Pt 17, Ch 1, 2.1 Materials 2.1.2* or be of alternative forms of construction, *see Pt 17, Ch 1, 2.1 Materials 2.1.3*.

3.2.2 The structure in way of Category ‘A' machinery spaces, galleys containing appliances of significant fire risk and other high risk areas is to be protected such that the material by itself or due to insulation provided can maintain its required strength at the end of 60 minutes exposure to the standard fire test.

3.2.3 Details of the method of construction, supported by calculations and/or fire test data, demonstrating compliance with *Pt 17, Ch 3, 3.2 Forms of construction – Structure 3.2.2* are to be submitted.

3.2.4 For aluminium alloy structures, the insulation is to be such that the temperature of the structural core does not rise more than 200°C above the ambient temperature at any time during the specified fire exposure.

3.2.5 For composite structures, the insulation is to be such that the temperature of the laminate does not rise more than the minimum temperature of deflection under load of the resin at any time during the specified fire exposure. The temperature of deflection under load is to be determined as in *Ch 14, 3.7 Tests for specific materials* of the Rules for Materials.

3.2.6 For structures in contact with sea-water, the required insulation should extend to at least 300 mm below the lightest waterline, *see also Pt 17, Ch 3, 2.6 Surface of insulation 2.6.1*.

3.3 Forms of construction – Fire divisions

3.3.1 Fire divisions required by *Pt 17, Ch 3, 3.4 Structural fire protection – Main vertical zones and horizontal zones* are to be constructed in accordance with the remaining paragraphs of *Pt 17, Ch 3, 3.3 Forms of construction – Fire divisions*.

3.3.2 Fire divisions using steel equivalent, or alternative forms of construction, may be accepted if it can be demonstrated that the material by itself due to insulation provided, has the fire resistance properties equivalent to ‘A' or ‘B' Class divisions.

3.3.3 Insulation required by *Pt 17, Ch 3, 3.3 Forms of construction – Fire divisions 3.3.2* is to be such that the temperature of the structural core does not rise above the point at which the structure would begin to lose its strength at any time during the applicable exposure to the standard fire test. For ‘A' Class divisions, the applicable exposure is 60 minutes, and for ‘B' Class divisions, the applicable exposure is 30 minutes.

3.3.4 For aluminium alloy structures, the insulation is to be such that the temperature of the structural core does not rise more than 200°C above the ambient temperature at any time during the applicable fire exposure.

3.3.5 For composite structures, the insulation is to be such that the temperature of the laminate does not rise more than the minimum temperature of deflection under load of the resin at any time during the applicable fire exposure. The temperature of deflection under load is to be determined as in *Ch 14, 3.7 Tests for specific materials* of the Rules for Materials.

3.4 Structural fire protection – Main vertical zones and horizontal zones

3.4.1 The hull, superstructure and deckhouses in way of accommodation and service spaces is to be subdivided into main vertical zones by ‘A' Class divisions, *see Pt 17, Ch 1, 2.4 Ship divisions and spaces 2.4.12*. These divisions are to have insulation values in accordance with *Table 3.3.2 Fire integrity of bulkheads separating adjacent spaces* and *Table 3.3.3 Fire integrity of decks separating adjacent spaces*.

3.4.2 As far as practicable, the bulkheads forming the boundaries of the main vertical zones above the bulkhead deck are to be in line with watertight subdivision bulkheads situated immediately below the bulkhead deck.

3.4.3 The bulkheads mentioned in *Pt 17, Ch 3, 3.4 Structural fire protection – Main vertical zones and horizontal zones 3.4.2* are to extend from deck to deck and to the shell or other boundaries.

Table 3.3.2 Fire integrity of bulkheads separating adjacent spaces

Spaces		**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**
Control stations	**(1)**	‘A-0’ *See* Note 3	‘A-0’	A-60’	‘A-0’	‘A-15’	‘A-60’	‘A-15’	‘A-60’	*See* Note 7
Corridors	**(2)**	—	C *See* Note 4	‘B-0’ *See* Note 4	‘A-0’ *See* Note 1 ‘B-0’ *See* Note 4	‘B-0’ *See* Note 4	A-60’	‘A-0’	‘A-15’ ‘A-0’ *See* Note 6	*See* Note 7
Accommodation spaces	**(3)**	—	—	C *See* Note 4	‘A-0’ *See* Note 1 ‘B-0’ *See* Note 4	‘B-0’ *See* Note 4	A-60’	‘A-0’	‘A-15’ ‘A-0’ *See* Note 6	*See* Note 7
Stairways	**(4)**	—	—	—	‘A-0’ *See* Note 1 ‘B-0’ *See* Note 4	‘A-0’ *See* Note 1 ‘B-0’ *See* Note 4	A-60’	‘A-0’	‘A-15’ ‘A-0’ *See* Note 6	*See* Note 7
Service spaces (low risk)	**(5)**	—	—	—	—	C *See* Note 4	A-60’	‘A-0’	‘A-0’	*See* Note 7
Machinery spaces of Category ‘A’ and spaces containing vehicles or craft with fuel in their tanks or lockers storing such fuels	**(6)**	—	—	—	—	—	‘A-60’ *See* Note 2	‘A-0’	‘A-60’	*See* Note 7
Other machinery spaces	**(7)**	—	—	—	—	—	—	‘A-0’ *See* Note 2	‘A-0’	*See* Note 7
Service spaces (high risk)	**(8)**	—	—	—	—	—	—	—	‘A-0’ *See* Note 2	*See* Note 7

Open decks	(9)	–	–	–	–	–	–	–	–	–

Note 1. For clarification as to which applies, *see Pt 17, Ch 3, 3.7 Structural fire protection – Protection of stairways and lifts in accommodation and service spaces*.

Note 2. Where spaces are of the same numerical category and Note 2 appears, a bulkhead or deck of the ratings shown in the Table is only required when the adjacent spaces are for a different purpose, e.g. in category (8), a galley next to a galley does not require a bulkhead, but a galley next to a paint room requires an 'A-0' Class bulkhead.

Note 3. Bulkheads separating the wheelhouse and chartroom from each other may be 'B-0' rating.

Note 4. For the application of *Pt 17, Ch 3, 3.4 Structural fire protection – Main vertical zones and horizontal zones 3.4.1* all 'B-0' and 'C' Class bulkheads where appearing in this Table are to be taken as 'A-0' Class.

Note 5. Fire insulation need not be fitted if the machinery space of category (7) has little or no fire risk.

Note 6. Where the spaces are protected by the sprinkler system on both sides of the division, the division may be 'A-0' Class. Where the sprinkler system only protects a space on one side of the division the rating is to be the higher of the two values given.

Note 7. The division is to be of steel, other equivalent material, or alternative forms of construction, but is not required to be of 'A' Class standard. However, where decks, except open decks, are penetrated for the passage of electric cables, pipes and vent ducts, such penetrations are to be made tight to prevent the passage of flame and smoke.

Note 8. For requirements for main vertical zones, *see Pt 17, Ch 3, 3.4 Structural fire protection – Main vertical zones and horizontal zones 3.4.1*.

Table 3.3.3 Fire integrity of decks separating adjacent spaces

		Space above								
Space below		**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**
Control stations	**(1)**	'A-0'	'A-0'	'A-0'	'A-0'	'A-0'	'A-60'	'A-0'	'A-0'	*See* Note 3
Corridors	**(2)**	'A-0'	*See* Note 3	*See* Note 3	'A-0'	*See* Note 3	'A-60'	'A-0'	'A-0'	*See* Note 3
Accommodation spaces	**(3)**	'A-60'	'A-0'	*See* Note 3	'A-0'	*See* Note 3	'A-60'	'A-0'	'A-0'	*See* Note 3
Stairways	**(4)**	'A-0'	'A-0'	'A-0'	*See* Note 3	'A-0'	'A-60'	'A-0'	'A-0'	*See* Note 3
Service spaces (low risk)	**(5)**	'A-15'	'A-0'	'A-0'	'A-0'	*See* Note 3	'A-60'	'A-0'	'A-0'	*See* Note 3
Machinery spaces of Category 'A' and spaces containing vehicles or craft with fuel in their tanks or lockers storing such fuels	**(6)**	'A-60'	'A-60'	'A-60'	'A-60'	'A-60'	'A-60'	'A-60' *See* Note 1	'A-60'	*See* Note 3
Other machinery spaces	**(7)**	'A-15'	'A-0'	'A-0'	'A-0'	'A-0'	'A-0'	*See* Note 3	'A-0'	*See* Note 3
Service spaces (high risk)	**(8)**	'A-60'	'A-30' 'A-0' *See* Note 2	'A-30' 'A-0' *See* Note 2	'A-30' 'A-0' *See* Note 2	'A-0'	'A-60'	'A-0'	'A-0'	*See* Note 3

Open decks **(9)**	*See* Note 3	*See* Note 3	*See* Note 3	*See* Note 3	*See* Note 3	*See* Note 3	*See* Note 3	*See* Note 3	—

Note 1. Fire insulation need not be fitted if the machinery space of category (7) has little or no fire risk.

Note 2. Where the spaces are protected by the sprinkler system on both sides of the division, the division may be 'A-0' Class. Where the sprinkler system only protects a space on one side of the division the rating is to be the higher of the two values given.

Note 3. The division is to be of steel, other equivalent material, or alternative forms of construction, but is not required to be of 'A' Class standard. However, where decks, except open decks, are penetrated for the passage of electric cables, pipes and vent ducts, such penetrations are to be made tight to prevent the passage of flame and smoke.

3.5 Structural fire protection of bulkheads within a main vertical zone

3.5.1 All such divisions may be faced with combustible materials.

3.5.2 When continuous 'B' Class ceilings and/or linings are fitted on both sides of the bulkhead, the portion of the bulkhead behind the continuous ceiling or lining is to be of material which in thickness and composition is acceptable the construction of 'B' Class divisions but which may meet 'B' Class standards only insofar as is reasonable and practicable.

3.5.3 All bulkheads required to be 'B' Class divisions, except corridor bulkheads prescribed in *Pt 17, Ch 3, 3.5 Structural fire protection of bulkheads within a main vertical zone 3.5.2* are to extend from deck to deck and to the shell or other boundaries unless continuous 'B' Class ceilings or linings fitted on both sides of the bulkhead are at least of the same fire resistance as the bulkhead, in which case the bulkhead may terminate at the continuous ceiling or lining.

3.6 Structural fire protection – Fire integrity of bulkheads and decks

3.6.1 In addition to complying with the specific provisions for fire integrity of bulkheads and decks mentioned elsewhere in this Section the minimum fire integrity of bulkheads and decks are to be as prescribed in *Table 3.3.2 Fire integrity of bulkheads separating adjacent spaces* and *Table 3.3.3 Fire integrity of decks separating adjacent spaces*.

3.6.2 For determining the appropriate fire integrity standards to be applied to divisions between adjacent spaces, such spaces are classified in *Table 3.3.2 Fire integrity of bulkheads separating adjacent spaces* and *Table 3.3.3 Fire integrity of decks separating adjacent spaces* according to their fire-risk as shown in space categories ***(1)*** to ***(9)*** . The title of each category is intended to be typical (general) rather than restrictive. The number in parentheses preceding each space category refers to the applicable column or row in the Tables.

(a) Control stations:

- Spaces containing emergency sources of power and lighting.
- Wheelhouse and chartroom.
- Spaces containing the ship's radio equipment.
- Fire-extinguishing rooms, fire-control stations and fire recording stations.
- Control room for propulsion machinery when located outside the machinery space.
- Spaces containing centralised fire-alarm equipment.

(b) Corridors:

- Guest and crew corridors and lobbies.

(c) Accommodation spaces:

- Spaces as defined in *Pt 17, Ch 1, 2.4 Ship divisions and spaces 2.4.5* excluding corridors.

(d) Stairways:

- Interior stairways, lifts and escalators (other than those wholly contained within the machinery spaces) and enclosures thereto.
- In this connection, a stairway which is enclosed only at one level is to be regarded as part of the space from which it is not separated by a fire door.

(e) Service spaces (low risk):

- Lockers and store-rooms having areas of less than 4 m^2 , drying rooms and laundries.

(f) Category 'A' machinery spaces, spaces containing vehicles or craft with fuel in their tanks, or lockers storing such fuels:

- Spaces as defined in *Pt 17, Ch 1, 2.4 Ship divisions and spaces 2.4.8*.

(g) Other machinery spaces:

- Spaces as defined in *Pt 17, Ch 1, 2.4 Ship divisions and spaces 2.4.9* excluding Category ‘A' machinery spaces.

(h) Service spaces (high risk):

- Galleys, pantries containing cooking appliances, paint and lamp rooms, lockers and store-rooms having areas of 4 m^2 or more, spaces for the storage of flammable liquids, bonded stores and workshops other than those forming part of the machinery spaces.

(i) Open decks:

- Open deck spaces and enclosed promenades having no fire-risk. Air spaces (the space outside superstructures and deckhouses).

3.6.3 Continuous ‘B' Class ceilings or linings, in association with the relevant decks or bulkheads, may be accepted as contributing, wholly or in part, to the required insulation and integrity of a division.

3.7 Structural fire protection – Protection of stairways and lifts in accommodation and service spaces

3.7.1 All stairways are to be of steel construction except where the use of other equivalent material is specially approved, and are to be within enclosures formed of ‘A' Class divisions, with positive means of closure at all openings, except that:

(a) A stairway connecting only two decks need not be enclosed, provided that the integrity of the deck is maintained by proper bulkheads or doors at one level to at least ‘B-0' Class. When a stairway is closed at one level, the stairway enclosure is to be protected in accordance with *Table 3.3.2 Fire integrity of bulkheads separating adjacent spaces* and *Table 3.3.3 Fire integrity of decks separating adjacent spaces*; and

(b) Stairways may be fitted in the open in a public space, provided that they lie wholly within such public space.

3.7.2 Stairway enclosures are to have a direct access to the corridors and to be of sufficient area to prevent congestion, having in view the number of persons likely to use them in an emergency. Within the perimeter of such stairway enclosures, only toilets and lockers of non-combustible material providing storage for safety equipment are permitted. Only public spaces, corridors, other escape stairways required by *Pt 17, Ch 3, 3.15 Structural fire protection – Means of escape 3.15.1.(e)*, pantries containing cooking appliances with an insignificant fire risk, *see Pt 17, Ch 3, 2.4 Structural fire protection 2.4.2*, and external areas are to have direct access to these stairway enclosures. Small corridors or lobbies may be used to separate an enclosed stairway from other spaces.

3.7.3 Lift trunks are to be so fitted as to prevent the passage of smoke and flame from one 'tween deck to another and are to be provided with means of closing so as to permit the control of draught and smoke.

3.8 Structural fire protection – Openings in ‘A' Class divisions

3.8.1 The construction of all doors and door frames in ‘A' Class divisions, with the means of securing them when closed, is to provide resistance to fire as well as to the passage of smoke and flame, as far as practicable, equivalent to that of the bulkheads in which the doors are situated. Such doors and door frames are to be constructed of steel or other equivalent material. Steel watertight doors need not be insulated.

3.8.2 It is to be possible for each door to be opened and closed from each side of the bulkhead by one person only.

3.8.3 Fire doors in main vertical zone bulkheads and stairway enclosures are to satisfy the following requirements:

(a) The doors shall be self-closing and be capable of closing with an angle of inclination of up to 3,5° opposing closure. The approximate time of closure for hinged fire doors is to be no more than 40 s and not less than 10 s from the beginning of their movement with the ship in the upright position. The approximate uniform rate of closure for sliding fire doors is to be no more than 0,2 m/s and no less than 0,1 m/s with the ship in the upright position.

(b) Remote-controlled sliding or power-operated doors are to be equipped with an alarm that will sound not less than 5 s but no more than 10 s before the door begins to move and will continue to sound until the door is completely closed. Doors designed to re-open upon contacting an object in its path are to re-open sufficiently to allow a clear passage of at least 0,75 m but not more than 1 m.

(c) All doors are to be capable of remote and automatic release from the continuously manned central control station, either simultaneously or in groups and also individually from a position at both sides of the door. Indication is to be provided at the fire control panel in the continuously manned central control station whether each of the remotely-controlled doors are closed. The release mechanism is to be so designed that the door will automatically close in the event of disruption of the control system or central power supply. Release switches shall have an on-off function to prevent automatic resetting of the system. Hold-back devices not subject to central control station release are not permitted.

(d) Local power accumulators for power-operated doors are to be located in the immediate vicinity of the doors. They are to have a capacity to enable the doors to be fully opened and closed at least 10 times using local controls.

(e) Double-leaf doors dependent on a latch to maintain their fire integrity are to be arranged so that the latch is automatically activated by the action of the closing doors.

(f) Doors which are power-operated and automatically closed, giving direct access to special category spaces need not be equipped with the alarms and remote release mechanism required by *Pt 17, Ch 3, 3.8 Structural fire protection – Openings in ‘A' Class divisions 3.8.3.(b)* and *Pt 17, Ch 3, 3.8 Structural fire protection – Openings in ‘A' Class divisions 3.8.3.(c)*.

(g) The components of the local control system are to be accessible for maintenance and adjusting.

3.8.4 Where ‘A' Class divisions are penetrated for the passage of electric cables, pipes, trunks, ducts, etc. or for girders, beams or other structural members, arrangements are to be made to ensure that the fire resistance is not impaired.

3.9 Structural fire protection – Openings in steel outer boundaries

3.9.1 The requirements for steel or other equivalent material on the outer boundaries of a yacht do not apply to glass partitions, windows and sidescuttles. The requirements of *Pt 17, Ch 3, 3.11 Structural fire protection – Windows and side scuttles 3.11.2* for such boundaries to have ‘A' class integrity are to be adhered to.

3.10 Structural fire protection – Openings in 'B' Class divisions

3.10.1 Doors and door frames in ‘B' Class divisions and means of securing them are to provide a method of closure which has resistance to fire as far as practicable equivalent to the divisions they serve, except that ventilation openings may be permitted in the lower portion of such doors. Where such openings are in or under a door the total net area of any such opening or openings is not to exceed 0,05 m^2 . When such an opening is cut in a door it is to be fitted with a grill made of non-combustible material. Bridging ducts are not allowed in fire divisions.

3.10.2 Cabin doors in ‘B' class divisions are to be self-closing. Hold-backs are not permitted.

3.10.3 Where ‘B' Class divisions are penetrated for the passage of electric cables, pipes, trunks, ducts, etc. or for the fitting of ventilation terminals, lighting fixtures and similar devices, arrangements are to be made to ensure that the fire resistance is not impaired.

3.11 Structural fire protection – Windows and side scuttles

3.11.1 Notwithstanding the requirements of *Table 3.3.2 Fire integrity of bulkheads separating adjacent spaces* and *Table 3.3.3 Fire integrity of decks separating adjacent spaces*, all windows and side scuttles in bulkheads separating accommodation and service spaces and control stations from weather are to be constructed with frames of steel or other suitable material. The glass is to be retained by a metal glazing bead or angle. Alternative forms of construction and retention will be considered.

3.11.2 Glass is not to be installed as an interior main vertical zone or stairway enclosure bulkhead.

3.11.3 For yachts having a freeboard length of 85 m and over, windows and side scuttles situated in the yacht's side shell below the life raft and escape slide embarkation areas and below lifeboat embarkation areas, are to have fire integrity of at least equal to ‘A-0' Class.

3.12 Structural fire protection – Details of construction

3.12.1 In accommodation and services spaces, control stations, corridors and stairways, air spaces enclosed behind ceilings, panelling or linings are to be suitably divided by close-fitting draught stops not more than 7 m apart. In the vertical direction, such spaces, including those behind linings of stairways, trunks, etc. are to be closed at each deck.

3.12.2 The draught stops are to be non-combustible and are to form a continuation above the ceiling of the bulkhead below or the other side of the panelling or lining to the bulkhead, as far as possible.

3.12.3 Where the structure or ‘A' Class divisions are required to be insulated, it is to be ensured that the heat from a fire is not transmitted through the intersections and terminal points of the divisions or penetrations to uninsulated boundaries. Where the insulation installed does not achieve this, arrangements are to be made to prevent this heat transmission by insulating the horizontal and vertical boundaries or penetrations for a distance of 450 mm.

3.13 Structural fire protection – Materials

3.13.1 Except in cargo spaces, mail rooms, baggage rooms, or refrigerated compartments, of service spaces, all insulation (e.g. fire and comfort) is to be of non-combustible materials. Partial bulkheads or decks used to subdivide a space for utility or artistic treatment are to have a non-combustible core.

3.13.2 The use of combustible materials is to be kept to a minimum.

3.13.3 Pipes penetrating ‘A' or ‘B' Class divisions are to be of approved materials having regard to the temperature such divisions are required to withstand.

3.13.4 Pipes conveying oil or combustible liquids through accommodation and service spaces are to be of approved materials having regard to the fire risk.

3.13.5 Materials readily rendered ineffective by heat are not to be used for overboard scuppers, sanitary discharges and other outlets which are close to the waterline and where the failure of the material in the event of fire would give rise to danger of flooding.

3.13.6 Primary deck coverings within accommodation spaces, service spaces and control stations are to be of a type which will not readily ignite, or give rise to toxic or explosive hazards at elevated temperatures. Reference is also to be made to the IMO FTP Code, Annex 1, *Part 2 - Smoke and Toxicity Test* and *Part 6 - Test for Primary Deck Coverings*.

3.13.7 Vapour barriers and adhesives used in conjunction with insulation, as well as insulation of pipe fittings for cold service systems need not be non-combustible, but they shall be kept to the minimum quantity practicable and their exposed surfaces shall have low flame spread characteristics.

3.13.8 All waste receptacles are to be constructed of non-combustible materials with no openings in the sides or bottom.

3.13.9 Furniture in the stairway enclosures is to be limited to seating. If required, it is to be fixed, limited to four seats on each deck in each stairway enclosure and is not to obstruct the escape route. Additional seating may be permitted in the main reception area within a stairway enclosure provided it is fixed and does not obstruct the escape route. Furniture is not permitted in corridors forming escape routes in cabin areas. Lockers for the storage of safety equipment may be permitted.

3.14 Structural fire protection – Surface of insulation

3.14.1 In spaces where penetration of oil products is possible, the surface of insulation is to be impervious to oil or oil vapours. Insulation boundaries are to be arranged to avoid immersion in oil spillages so far as is practicable.

3.15 Structural fire protection – Means of escape

3.15.1 Stairways and ladders are to be arranged to provide ready means of escape to the survival craft embarkation deck from all guest and crew spaces and from spaces in which the crew is normally employed, other than machinery spaces. In particular, the following provisions are to be complied with:

(a) Below the bulkhead deck, two means of escape, at least one of which is to be independent of watertight doors, are to be provided for each watertight compartment or similarly restricted space or group of spaces. One of these means of escape may be dispensed with, due regard being paid to the nature and the location of spaces concerned, and to the number of persons who normally might be accommodated or employed there.

(b) Above the bulkhead deck, there are to be at least two practical means of escape from each main vertical zone or similarly restricted space or group of spaces, at least one of which is to give access to a stairway forming a vertical escape.

(c) If a radio-telegraph station has no direct access to the open deck, two means of escape from or access to such station are to be provided, one of which may be a porthole or window of sufficient size or other satisfactory means to provide an emergency escape.

(d) A corridor, lobby, or part of a corridor from which there is only one route of escape is not to exceed 7 m. Where accommodation arrangements are such that access to compartments is through another compartment, as is often the case with an Owner's suite, a second means of escape is to be provided. The second escape route is to be as remote as possible from the main escape route. The second means of escape may be through portholes or hatches of adequate size, leading to the open deck.

(e) At least one of the means of escape required by *Pt 17, Ch 3, 3.15 Structural fire protection – Means of escape 3.15.1* and *Pt 17, Ch 3, 3.15 Structural fire protection – Means of escape 3.15.1.(b)* is to be by means of a readily accessible enclosed stairway, which will provide continuous fire shelter from the level of its origin to the appropriate survival craft embarkation decks, or the uppermost weather deck if the embarkation deck does not extend to the main vertical zone being considered. In the latter case, direct access to the embarkation deck by external open stairways and passageways is to be provided and

is to have emergency lighting and slip-free surfaces underfoot. Boundaries facing external open stairways and passageways forming part of an escape route and boundaries in such a position that their failure during a fire would impede escape to the embarkation deck, are to have fire integrity and insulation values in accordance with *Table 3.3.2 Fire integrity of bulkheads separating adjacent spaces* and *Table 3.3.3 Fire integrity of decks separating adjacent spaces*. The widths, number and continuity of escape routes are to be as follows:

(i) Stairways are to be not less than 900 mm clear width between handrails. Stairways are to be fitted with handrails on each side. The minimum clear width of stairways is to be increased by 10 mm for every person provided for in excess of 90 persons. The maximum clear width between handrails where stairways are wider than 900 mm is to be 1800 mm. The total number of persons to be evacuated by such stairways is to be two-thirds of the crew and total number of passengers in the areas served by such stairways.

(ii) Stairways with a clear width in excess of 900 mm are to be aligned in a fore-and-aft direction.

(iii) Doorways, corridors and intermediate landings included in the means of escape are to have widths sized in the same manner as the stairways.

(iv) Stairways are not to exceed 3,5 m vertical rise without the provision of a landing and are not to have angle of inclination greater than 45° to the horizontal.

(v) With the exception of intermediate landings, landings at each deck level shall not be less than 2 m^2 in area and shall increase by 1 m^2 for every 10 persons provided for in excess of 20 persons but need not exceed 16 m^2, except for those landings serving public spaces having direct access onto the stairway enclosure. Intermediate landings shall be sized in accordance with paragraph (iii).

(f) Protection of access from the stairway enclosures to the survival craft embarkation areas are to comply with the requirements of *Table 3.3.2 Fire integrity of bulkheads separating adjacent spaces* and *Table 3.3.3 Fire integrity of decks separating adjacent spaces*.

(g) Where public spaces span three or more open decks, contain combustibles such as furniture and give access to other enclosed spaces, each level within the space is to have two means of escape, one of which is to give direct access to an enclosed vertical means of escape meeting the requirements of *Pt 17, Ch 3, 3.15 Structural fire protection – Means of escape 3.15.1.(e)*.

(h) Where a dispensation has been granted under the provisions of *Pt 17, Ch 3, 3.15 Structural fire protection – Means of escape 3.15.1*, a safe means of escape is to be provided. Stairways are to be provided with handrails on both sides and are to have a clear width between handrails of not less than 800 mm.

3.15.2 Two means of escape are to be provided from each machinery space. In particular, the following provisions are to be complied with:

(a) Where the space is below the bulkhead deck the two means of escape are to consist of either:

(i) Two sets of steel ladders and walkways as widely separated as possible, leading to doors in the upper part of the space similarly separated and from which access is provided to the appropriate survival craft embarkation decks. One of these ladders is to provide continuous fire shelter from the lower part of the space to a safe position outside the space. This shelter is to be of steel or equivalent material, insulated where necessary, and provided with a self closing door of steel or equivalent material at the lower end. If access is provided at other levels each level is to be provided with a steel or equivalent material; or

(ii) One steel ladder leading to a door in the upper part of the space from which access is provided to the embarkation deck and additionally, in the lower part of the space and in a position well separated from the ladder referred to, a steel or equivalent material door capable of being operated from each side and which provides access to a safe escape route from the lower part of the space to the embarkation deck.

(b) Where the space is above the bulkhead deck, the two means of escape are to be as widely separated as possible and the doors leading from such means of escape are to be in a position from which access is provided to the appropriate survival craft embarkation decks. Where such means of escape require the use of ladders these are to be of steel.

3.15.3 One of the means of escape from any such space required by *Pt 17, Ch 3, 3.15 Structural fire protection – Means of escape 3.15.2* may be dispensed with, so long as either a door or a steel ladder and walkways provides a safe escape route to the embarkation deck, due regard being paid to the nature and location of the space and whether persons are normally employed in that space.

3.15.4 Two means of escape are to be provided from a machinery control room located inside a machinery space, at least one of which is to provide continuous fire shelter to a safe position outside the machinery space.

3.15.5 Adequate deck area is to be provided at muster stations and embarkation areas having due regard to the expected number of persons.

3.16 Ventilation systems

3.16.1 Ventilation ducts are to be of steel or another non-combustible material subject to the other material having passed a standard fire test in accordance with Annex 1: Part 3 of the FTP Code as a non-load bearing structure for 30 minutes following the requirements for testing 'B' class divisions. Short lengths of ducts not exceeding 2 m in length and with a cross-section not exceeding 0,02 m^2 need not be non-combustible, subject to these ducts being:

(a) of a material that has low flame spread characteristics;
(b) used at the end of the ventilation device; and
(c) situated not less than 600 mm, measured along the duct, from an opening in an 'A' or 'B' Class division including continuous 'B' Class ceilings.

3.16.2 Where the ventilation ducts with a free cross-sectional area exceeding 0,02 m^2 but not more than 0,075 m^2 pass through Class 'A' bulkheads or decks, the openings are to be lined with a steel sheet sleeve unless the ducts passing through the bulkheads or decks are of steel in the vicinity of passage through the deck or bulkhead and the ducts and sleeves are to comply in this part with the following:

(a) Steel ducts, or sleeves lining such ducts are to have a thickness of at least 3 mm and a length of at least 900 mm. When passing through bulkheads, this length is to be divided preferably into 450 mm on each side of the bulkhead. These ducts, or sleeves lining such ducts, are to be provided with fire insulation. The insulation is to have at least the same fire integrity as the bulkhead or deck through which the duct passes.
(b) Steel ducts with a free cross-sectional area exceeding 0,075 m^2 are to be fitted with fire dampers in addition to the requirements of *Pt 17, Ch 3, 3.16 Ventilation systems 3.16.2*. The fire damper is to operate automatically but is also to be capable of being closed manually from both sides of the bulkhead or deck. The damper is to be provided with an indicator which shows whether the damper is open or closed. Fire dampers are not required, however, where ducts pass through spaces surrounded by 'A' Class divisions, without serving those spaces, provided those ducts have the same fire integrity as the divisions which they penetrate.
(c) Compliance with *Pt 17, Ch 3, 3.8 Structural fire protection – Openings in 'A' Class divisions 3.8.4*.

3.16.3 Ventilation ducts with a free cross-sectional area exceeding 0,02 m^2 passing through 'B' Class bulkheads are to be lined with steel sheet, or other equivalent material, sleeves of 900 mm in length divided preferably into 450 mm on each side of the bulkheads unless the duct is of steel for this length, *see also Pt 17, Ch 3, 3.10 Structural fire protection – Openings in 'B' Class divisions*.

3.16.4 Ducts provided for the ventilation of Category 'A' machinery spaces, galleys, spaces containing vehicles or craft with fuel in their tanks or lockers storing such fuels, are not to pass through accommodation spaces, service spaces or control stations unless the ducts are:

(a) either:
   (i) constructed of steel having a thickness of at least 3 mm for ducts with a free cross-sectional area of less than 0,075 m^2, at least 4 mm for ducts with a free cross-sectional area of between 0,075 m^2 and 0,45 m^2, and at least 5 mm for ducts with a free cross-sectional area of over 0,45 m^2;
   (ii) suitably supported and stiffened;
   (iii) fitted with automatic fire dampers close to the boundaries penetrated; and
   (iv) insulated to 'A-60' Class standard from the machinery spaces, galleys, spaces containing vehicles or craft with fuel in their tanks or lockers storing such fuels, to a point at least 5 m beyond each fire damper;
(b) or:
   (i) constructed of steel in accordance with *Pt 17, Ch 3, 3.16 Ventilation systems 3.16.4* and *Pt 17, Ch 3, 3.16 Ventilation systems 3.16.4.(a).(ii)*; and
   (ii) insulated to 'A-60' Class standard throughout the accommodation spaces, service spaces or control stations;

except that penetrations of main zone divisions are also to comply with *Pt 17, Ch 3, 3.16 Ventilation systems 3.16.8*.

3.16.5 Ducts provided for ventilation to accommodation spaces, service spaces or control stations are not to pass through such spaces, unless, where they pass through Category 'A' machinery spaces, galleys, spaces containing vehicles or craft with fuel in their tanks, or lockers storing such fuels, the ducts:

(a) either:
   (i) are constructed of steel in accordance with *Pt 17, Ch 3, 3.16 Ventilation systems 3.16.4* and *Pt 17, Ch 3, 3.16 Ventilation systems 3.16.4.(a).(ii)*;

(ii) are fitted with automatic fire dampers close to the boundaries penetrated; and

(iii) have the integrity of boundaries of the machinery space, galley, spaces containing vehicles or craft with fuel in their tanks, or lockers storing such fuels, maintained at the penetrations; are insulated to 'A 60' class standard from the boundaries of the spaces they serve to a point at least 5 m beyond each fire damper.

(b) or:

(i) are constructed of steel in accordance with *Pt 17, Ch 3, 3.16 Ventilation systems 3.16.4* and *Pt 17, Ch 3, 3.16 Ventilation systems 3.16.4.(a).(ii)*; and

(ii) are insulated to 'A-60' Class standard within the machinery space, galley or spaces containing vehicles or craft with fuel in their tanks or lockers storing such fuels;

except that penetration of main zone divisions is also to comply with *Pt 17, Ch 3, 3.16 Ventilation systems 3.16.8*

3.16.6 Such measures as are practicable are to be taken in respect of control stations outside machinery spaces in order to ensure that ventilation, visibility and freedom from smoke are maintained, so that in the event of fire the machinery and equipment contained therein may be supervised and continue to function effectively. Alternative and separate means of air supply are to be provided; air inlets of the two sources of supply are to be so disposed that the risk of both inlets drawing in smoke simultaneously is minimised. Such requirements need not apply to control stations situated on, and opening on to, an open deck, or where local closing arrangements would be equally effective.

3.16.7 Where they pass through accommodation spaces or spaces containing combustible materials, the exhaust ducts from galley ranges are to comply with *Pt 17, Ch 3, 3.16 Ventilation systems 3.16.4*. Such exhaust ducts are to be fitted with:

(a) a grease trap readily removable for cleaning;

(b) an automatically and remotely operated fire damper located in the lower end of the duct at the junction between the duct and the galley range hood and, in addition, a remotely operated fire damper in the upper end of the duct close to the outlet of the duct;

(c) arrangements, operable from within the galley, for shutting off the exhaust and supply fans; and

(d) fixed means for extinguishing a fire within the duct.

3.16.8 Where it is necessary that a ventilation duct passes through a main vertical zone division, a fail-safe automatic closing fire damper is to be fitted adjacent to the division. The damper is also to be capable of being manually closed from each side of the division. The operating position is to be readily accessible and be clearly and prominently marked. The duct between the division and the damper is to be of steel or other equivalent material and, if necessary, insulated to comply with *Pt 17, Ch 3, 3.8 Structural fire protection – Openings in 'A' Class divisions 3.8.4*. The damper is to be fitted on at least one side of the division with a visible indicator showing the operating position of the damper.

3.16.9 Where public spaces span three or more open decks and contain combustibles such as furniture and other enclosed spaces, the space is to be equipped with a smoke extraction system. The smoke extraction system is to be activated by the smoke detection system required by *Pt 17, Ch 4, 2 Fixed fire detection and fire-alarm systems* and is to be capable of manual control. The fans are to be capable of exhausting the entire volume within the space in not more than 10 min.

3.16.10 The main inlets and outlets of all ventilation systems are to be capable of being closed from outside the spaces being ventilated.

3.16.11 Power ventilation of accommodation spaces, service spaces, control stations and machinery spaces is to be capable of being stopped from an easily accessible position outside the space being served. This position should not be readily cut off in the event of a fire in the spaces served. The means provided for stopping the power ventilation of the machinery spaces is to be entirely separate from the means provided for stopping ventilation of other spaces, *see also Pt 16, Ch 2, 17.6 Fire safety stops*.

3.16.12 Reference is also made to *Pt 17, Ch 3, 2.8 Ventilation systems 2.8.4* to *Pt 17, Ch 3, 2.8 Ventilation systems 2.8.7*, *Pt 17, Ch 3, 2.8 Ventilation systems 2.8.9* and *Pt 17, Ch 3, 3.10 Structural fire protection – Openings in 'B' Class divisions 3.10.1*.

3.16.13 Ducts provided for exhaust ventilation from laundries are to be fitted with:

(a) filters readily removable for cleaning purposes;

(b) a fire damper located in the lower end of the duct which is automatically and remotely operated;

(c) remote-control arrangements for shutting off the exhaust fans, and supply fans from within the space and for operating the fire damper mentioned in (b); and

(d) suitably located hatches for inspection and cleaning.

3.16.14 Where a ventilation room serves only an adjacent machinery space of Category A and there is no fire division between the ventilation room and the machinery space, the means for closing the ventilation duct or ducts serving the machinery space shall be located outside of the ventilation room and machinery space.

3.16.15 Where a ventilation room serves a machinery space of Category A as well as other spaces and is separated from the machinery space by a ‘A-0’ class division, including penetrations, the means for closing the ventilation duct or ducts for the machinery space can be located in the ventilation room.

3.16.16 Fire dampers required by *Pt 17, Ch 3, 3.16 Ventilation systems 3.16.2*, *Pt 17, Ch 3, 3.16 Ventilation systems 3.16.4*, *Pt 17, Ch 3, 3.16 Ventilation systems 3.16.5*, *Pt 17, Ch 3, 3.16 Ventilation systems 3.16.7* upper end fire damper only, *Pt 17, Ch 3, 3.16 Ventilation systems 3.16.8* and *Pt 17, Ch 3, 3.16 Ventilation systems 3.16.13*, including relevant means of operation are to be fire tested. Reference is also to be made to IMO FTP Code, Annex 1, *Part 3 - Test for “A”, “B” and “F” Class Divisions*. The lower end fire damper required by *Pt 17, Ch 3, 3.16 Ventilation systems 3.16.7* must be of steel and capable of stopping the draught.

3.17 Fuel oil arrangements

3.17.1 In a yacht in which fuel oil is used, the arrangements for the storage, distribution and utilisation of the fuel oil are to be such as to ensure the safety of the yacht and persons on board. For details, *see Pt 15, Ch 3 Machinery Piping Systems*.

3.17.2 As far as practicable, fuel oil tanks are to be part of the yacht's structure and are to be located outside Category ‘A' machinery spaces.

3.17.3 Where fuel oil tanks, other than double bottom tanks, are necessarily located adjacent to or within Category ‘A' machinery spaces, at least one of their vertical sides is to be contiguous to the machinery space boundaries, and is preferably to have a common boundary with the double bottom tanks, and the area of the tank boundary common with the machinery spaces is to be kept to a minimum. Where the vertical boundary of a tank directly exposed to a machinery space meets the yacht's side plating at an acute angle, a small horizontal surface at the base of the tank, necessary to accommodate practical constructional considerations may be permitted. If the arrangement of the machinery is such that a tank with a large horizontal surface at the base is necessary then a cofferdam with suitable ventilation arrangements, to protect the base of the tank from the effect of a machinery space fire, will be specially considered. *See also Pt 15, Ch 3 Machinery Piping Systems*. Fuel oil tanks situated within the boundaries of Category ‘A' machinery spaces are not to contain fuel oil having a flashpoint of less than 60°C. The use of free-standing fuel oil tanks is prohibited.

3.18 Lubricating oil arrangements

3.18.1 The arrangements for the storage, distribution and utilisation of oil used in pressure lubrication systems are to be such as to ensure the safety of the yacht and persons on board, *see also Pt 15, Ch 3 Machinery Piping Systems*.

3.19 Arrangements for other flammable oils

3.19.1 The arrangements for the storage, distribution and utilisation of other flammable oils employed under pressure in power transmission systems, control and activating systems and heating systems are to be such as to ensure the safety of the ship and persons on board, *see also Pt 15, Ch 3 Machinery Piping Systems*.

3.20 Prohibition of carriage of flammable oils in forepeak tanks

3.20.1 Fuel oil, lubricating oil and other flammable oils are not to be carried in forepeak tanks.

3.21 Special arrangements in Category ‘A' machinery spaces

3.21.1 Openings are to be provided with closing appliances constructed so as to maintain the fire integrity of the machinery space boundaries.

3.21.2 Doors other than power operated watertight doors, are to be so arranged that positive closure is assured in case of fire in the space, by power-operated closing arrangements or by the provision of self-closing doors capable of closing against an inclination of 3,5° opposing closure and having a fail-safe hook-back facility, provided with a remotely operated release device.

3.21.3 Windows are not to be fitted in machinery space boundaries. This does not preclude the use of glass in control rooms within the machinery spaces.

3.21.4 Means of control are to be provided for:

(a) closure of openings which normally allow exhaust ventilation, and closure of ventilator dampers;
(b) permitting the release of smoke;

(c) closing power-operated doors or actuating release mechanism on doors other than power-operated watertight doors;
(d) stopping ventilating fans; and
(e) stopping forced and induced draught fans, fuel oil transfer pumps, fuel oil unit pumps and other similar fuel pumps.

3.21.5 The controls required in *Pt 17, Ch 3, 3.21 Special arrangements in Category ‘A' machinery spaces 3.21.4* are to be located outside the space concerned, where they will not be cut off in the event of fire in the space they serve. Such controls and the controls for any required fire-extinguishing system are to be situated at one control position or grouped in as few positions as possible. Such positions are to have a safe access from the open deck, *see also Pt 15, Ch 3, 4.5 Control of pumps 4.5.1* and *Pt 15, Ch 3, 4.9 Valves on deep tanks and their control arrangements 4.9.2*.

3.21.6 When access to any Category ‘A' machinery space is provided at a low level from an adjacent space there is to be provided near the watertight door, a light steel fire-screen door operable from each side.

3.22 Arrangements for gaseous fuel for domestic purposes

3.22.1 Where gaseous fuel is used for domestic purposes, the arrangements for the storage, distribution and utilisation of the fuel is to be such that, having regard to the hazards of fire and explosion which the use of such fuel may entail, the safety of the yacht and the persons on board is preserved. The installation is to be in accordance with recognised National or International Standards.

3.22.2 Storage lockers for gas cylinders are to be provided with:

(a) effective ventilation;
(b) an outward-opening door accessible directly to the open deck; and
(c) gas-tight boundaries, including doors and other means of closing any openings therein, which form boundaries between such lockers and adjoining enclosed spaces.

3.23 Space heaters

3.23.1 Space heaters, if used, are to be fixed in position and so constructed as to reduce fire risks to a minimum. The design and location of these units is to be such that clothing, curtains or other similar materials cannot be scorched or set on fire by heat from the unit.

3.24 Fixed fire detection and fire-alarm systems

3.24.1 A fixed fire detection and fire-alarm system is to be installed in any machinery space and is to comply with the requirements of *Pt 16, Ch 1, 2.8 Fire detection and fire alarm systems*.

3.24.2 A fixed fire detection and fire-alarm system is to be fitted in all stairways (including lift and dumbwaiter trunks), service spaces, control stations and accommodation spaces (except toilets, bathrooms, void spaces, etc.). The fixed fire detection and fire-alarm system is to be installed in accordance with *Pt 17, Ch 4, 2 Fixed fire detection and fire-alarm systems*.

3.24.3 All yachts at all times when at sea, or in port (except when out of service), are to be so equipped as to ensure that any initial fire-alarm is immediately received by a responsible member of the crew.

3.24.4 A special alarm, operated from the navigating bridge or fire-control station, is to be fitted to summon the crew.

3.24.5 For yachts having a freeboard length of 85 m or more, a public address system is to be available throughout the accommodation and service spaces and control stations and open decks. The arrangements are to comply with *Pt 16, Ch 2, 18.3 Public address system*.

3.25 Fire pumps and fire main system

3.25.1 **Application**. Every yacht is to be provided with fire pumps in accordance with this Section. Fire mains, hydrants and hoses are also to be provided as required by this Section.

3.25.2 **Capacity of fire pumps**:

(a) The fire pumps required are to be capable of delivering for fire-fighting purposes a quantity of water, at the pressure specified in *Pt 17, Ch 3, 3.25 Fire pumps and fire main system 3.25.5* of not less than two-thirds of the quantity required to be dealt with by the bilge pumps when employed for bilge pumping. For number and capacity of bilge pumps, *see Pt 15, Ch 2 Ship Piping Systems*
(b) As an alternative to (a) the capacity of fire pumps may be determined by hydrostatic calculations based on the requirement of *Pt 17, Ch 3, 3.25 Fire pumps and fire main system 3.25.5*.

(c) Where more pumps than the minimum number of required pumps are installed the capacity of such additional pumps will be specially considered.

3.25.3 **Fire pumps:**

(a) In yachts of 4000 tons gross or more, at least three independently driven fire pumps are to be provided and, in yachts of less than 4000 tons gross, at least two such fire pumps.
(b) Sanitary, ballast, bilge or general service pumps may be accepted as fire pumps, provided that they are not normally used for pumping oil, and that, if they are subject to occasional duty for the transfer or pumping of fuel oil, suitable changeover arrangements are fitted.
(c) In yachts classed for navigation in ice, the fire pump sea inlet valves are to be provided with clearing arrangements, *see Pt 1, Ch 2, 3.8 Other hull notations 3.8.1*.
(d) The arrangement of sea connections, fire pumps and their sources of power are to be such as to ensure that in the event of a fire in any one compartment, all the fire pumps will not be put out of action.
(e) The arrangements for the ready availability of water supply are to be as follows:
   (i) In yachts of 1000 gross tons or more, or any yacht of an alternative form of construction, the arrangements are to be such that at least one effective jet of water is immediately available from any hydrant in an interior location and so as to ensure the continuation of the output of water by the automatic starting of a required fire pump.
   (ii) Yachts not provided with arrangements complying with (i), but to which a UMS notation is to be assigned, are to have remote starting of a required fire pump from the navigating bridge and fire-control station, if any.
(f) Relief valves are to be provided in conjunction with any fire pump if the pump is capable of developing a pressure exceeding the design pressure of the water service pipes, hydrants and hoses. These valves are to be so placed and adjusted as to prevent excessive pressure in any part of the fire main system.
(g) Where centrifugal pumps are provided in order to comply with this sub-Section, a non-return valve is to be fitted in the pipe connecting the pump to the fire main.

3.25.4 **Fire main:**

(a) The diameter of the fire main is to be based on the required capacity of two fire pumps, and the diameter of the water service pipes are to be sufficient to ensure an adequate supply of water for the simultaneous operation of at least two fire-hoses. In general, the diameter of the fire main is to be not less than:

$$d = \left(L_{\text{pp}}/1,2\right) + 25 \text{ mm}$$

but need not exceed 180 mm in yachts, and in no case to be less than 50 mm

where

d = internal diameter of the fire main, in mm

L_{pp} = length of yacht measured between perpendiculars, in metres, as defined in *Pt 3, Ch 1, 6.2 Principal particulars 6.2.2*.

(b) The wash deck line may be used as a fire main provided that the requirements of this sub-Section are satisfied.
(c) All exposed water pipes for fire-extinguishing are to be provided with drain valves for use in frosty weather. The valves are to be located where they will not be damaged.

3.25.5 **Pressure in the fire main:**

(a) The fire pumps, associated piping and fire main are to be so designed that the following minimum pressures will be maintained at all hydrants under conditions where two fire pumps required by *Pt 17, Ch 3, 3.25 Fire pumps and fire main system 3.25.3* are simultaneously delivering water to the fire main of the size required by *Pt 17, Ch 3, 3.25 Fire pumps and fire main system 3.25.4* through adjacent nozzles of sizes required by *Pt 17, Ch 3, 3.25 Fire pumps and fire main system 3.25.9*:

4000 tons gross and over	4 bar (0,4 N/mm^2)
Less than 4000 tons gross	3 bar (0,3 N/mm^2)

(b) The maximum pressure at any hydrant shall not exceed that at which the effective control of a fire-hose can be demonstrated.

3.25.6 **Number and position of hydrants:**

(a) The number and position of the hydrants are to be such that at least two jets of water not emanating from the same hydrant, one of which is to be from a single length of hose, may reach any part of the yacht normally accessible to the guests and crew while the yacht is being navigated. In yachts of 1000 tons gross or more, at least two hydrants are to be provided in the machinery spaces; in smaller yachts one hydrant will be accepted.

(b) In the accommodation, service and machinery spaces, the number and position of hydrants are to be such that the requirements of (a) may be complied with when all watertight doors and all doors in main vertical zone bulkheads are closed.

(c) Where access is provided to a machinery space of Category ‘A' at a low level, two hydrants are to be provided external to, but near the entrance to that machinery space.

3.25.7 **Pipes and hydrants:**

(a) Materials readily rendered ineffective by heat are not to be used for fire mains. Where steel pipes are used, they are to be galvanised internally and externally. Cast iron pipes are not acceptable. The pipes and hydrants are to be so placed that the fire-hoses may be easily coupled to them. The arrangement of pipes and hydrants shall be such as to avoid the possibility of freezing. Unless one hose and nozzle is provided for each hydrant in the yacht, there is to be complete interchangeability of hose couplings and nozzles.

(b) A valve is to be fitted at each fire hydrant so that any fire-hose may be removed while the fire pump is at work.

(c) Isolating valve(s) to isolate the section of the fire main within the Category ‘A' machinery space containing the main fire pump(s) from the rest of the fire main are to be fitted in an easily accessible and tenable position outside the Category ‘A' machinery space. The fire main is to be so arranged that when the isolating valve(s) is shut, all the hydrants on the yacht, except those in the Category ‘A' machinery space referred to above, can be supplied with water by a fire pump not located in this Category ‘A' machinery space through pipes which do not enter this space.

3.25.8 **Fire-hoses:**

(a) Fire-hoses are to be of approved non-perishable material. The hoses are to be sufficient in length to project a jet of water to any of the spaces in which they may be required to be used. Their length, in general, is not to exceed 18 m. Each hose is to be provided with a nozzle and the necessary couplings. Fire-hoses, together with any necessary fittings and tools, are to be kept ready for use in conspicuous positions near the water service hydrants or connections.

(b) There is to be at least one fire-hose for each of the hydrants required by *Pt 17, Ch 3, 3.25 Fire pumps and fire main system 3.25.6*.

3.25.9 **Nozzles**:

(a) For the purpose of this Chapter, standard nozzle sizes are to be 12 mm, 16 mm or 19 mm, or as near thereto as possible, so as to make full use of the maximum discharge capacity of the fire pumps.

(b) For accommodation and service spaces, the nozzle size need not exceed 12 mm.

(c) For machinery spaces and exterior locations, the nozzle size is to be such as to obtain the maximum discharge possible from two jets at the pressure indicated in *Pt 17, Ch 3, 3.25 Fire pumps and fire main system 3.25.5* from the smallest pump, however a nozzle size greater than 19 mm need not be used.

(d) All nozzles are to be of an approved dual purpose type (i.e. spray/jet type) incorporating a shut-off.

3.25.10 **Location and arrangement of water pumps, etc. for other fire-extinguishing systems**. Pumps required for the provision of water for other fire-extinguishing systems required by this Chapter, are to have their sources of power and their controls installed outside the space or spaces protected by such systems and are to be so arranged that a fire in the space or spaces protected will not put any such system out of action.

3.25.11 **International shore connection**. At least one is to be provided.

3.26 Fire-extinguishing arrangements in spaces containing internal combustion machinery

3.26.1 Category ‘A' machinery spaces containing internal combustion machinery are to be provided with:

(a) one of the fire-extinguishing systems described in *Pt 17, Ch 4, 3 Fixed fire-extinguishing systems in machinery spaces*;

(b) at least one set of portable air-foam equipment complying with *Pt 17, Ch 3, 3.29 Automatic sprinkler, fire detection and fire-alarm system*;

(c) in each such space approved foam type fire-extinguishers, each of at least 45 litres capacity or equivalent, sufficient in number to enable foam or its equivalent to be directed on to any part of the fuel and lubricating oil pressure systems, gearing and other fire hazards; and

(d) a sufficient number of portable foam extinguishers or equivalent are to be located so that no point in the space is more than 10 m walking distance from an extinguisher and that there are at least two such extinguishers in each such space.

3.26.2 Machinery spaces in yachts which are constructed mainly or wholly with alternative forms of construction, containing internal combustion machinery, are to comply with the requirements of *Pt 17, Ch 3, 3.26 Fire-extinguishing arrangements in spaces containing internal combustion machinery 3.26.1*.

3.27 Fire-extinguishing arrangements in spaces containing fuel oil units

3.27.1 Category ‘A' machinery spaces containing fuel oil units are to be provided with one of the fixed fire-extinguishing systems described in *Pt 17, Ch 4, 3 Fixed fire-extinguishing systems in machinery spaces*.

3.27.2 There are to be at least two portable foam extinguishers or equivalent in each space in which a part of the fuel oil unit is situated.

3.28 Limitations on the use of oil as a fuel

3.28.1 For the limitations on the use of oil as a fuel, *see Pt 15, Ch 3 Machinery Piping Systems*.

3.29 Automatic sprinkler, fire detection and fire-alarm system

3.29.1 A fixed automatic sprinkler, fire detection and fire-alarm system, or equivalent system (e.g. watermist), is to be fitted in all stairways, service spaces, control stations and accommodation spaces except spaces which afford no fire risk such as void spaces.

3.29.2 The arrangements are to be in accordance with *Pt 17, Ch 4, 1 Automatic sprinkler, fire detection and fire-alarm systems*.

3.30 Fixed fire-extinguishing systems not required by this Section

3.30.1 Where a fixed fire-extinguishing system not required by this Section is installed, the arrangement is to comply with the relevant requirements of this Chapter.

3.31 Portable foam applicator

3.31.1 A portable foam applicator unit is to consist of an air foam nozzle of an inductor type capable of being connected to the fire main by a fire-hose, together with a portable tank containing at least 20 litres of foam-making liquid and one spare tank. The nozzle is to be capable of producing effective foam, suitable for extinguishing an oil fire, at the rate of at least 1,5 m^3 /min

3.32 Portable fire-extinguishers

3.32.1 All fire-extinguishers are to comply with the requirements of *Pt 17, Ch 4, 6 Fire-extinguishers (portable and non-portable)*.

3.32.2 The extinguishers are to be stowed in readily accessible positions.

3.32.3 One of the portable fire-extinguishers, or the portable fire-extinguisher, dedicated for use in any space is to be stowed near the entrance to that space.

3.32.4 At least one portable fire-extinguisher is to be located so that it can easily be reached from the main steering position of the yacht.

3.32.5 Accommodation spaces, service spaces and control stations are to be provided with a sufficient number of portable fire-extinguishers to ensure that at least one extinguisher will be readily available for use in every compartment. In any case, their number is to be not less than five.

3.32.6 Where cooking facilities are provided, a portable fire-extinguisher of a type appropriate to the energy source used is to be located in a position readily accessible for use in the event of a fire.

3.33 Fire blanket

3.33.1 A fire blanket is to be installed in all galleys.

3.34 Protection of spaces containing vehicles or craft with fuel in their tanks, or lockers storing such fuels

3.34.1 Spaces containing vehicles or craft with fuel in their tanks, or lockers storing such fuels, are to be provided with the following:

(a) A fixed fire detection and fire-alarm system complying with the requirements of *Pt 16, Ch 1, 2.8 Fire detection and fire alarm systems*.

(b) A manually-operated water spray deluge system having a water application rate of 5 litres per square metre of deck area per minute. Where the deck height does not exceed 2,5 m, an application rate of 3,5 litres per square metre of deck area per minute will be accepted. Adequate drainage of the protected spaces is to be provided generally in accordance with the requirements for vehicle or cargo space, *see Pt 3, Ch 4, 9.4 Scupper arrangements 9.4.4*. The drainage piping and connections for the space are to be non-combustible. Other fixed fire-extinguishing systems may be permitted, provided they are not less effective in controlling the type of fire likely to occur.
(c) At least two portable foam extinguishers, or equivalent;
(d) An independent mechanical ventilation system, which is entirely separate from other ventilation systems, providing at least six air changes per hour. The ducted air is not to pass through other spaces, except as allowed under *Pt 17, Ch 3, 3.16 Ventilation systems 3.16.4*, or vent into areas where it could be drawn into accommodation areas or cause undue hazard.
(e) Electrical equipment of a safe type is to be provided, *see Pt 16, Ch 2, 14 Electrical equipment for use in explosive atmospheres*
(f) Prominently displayed 'No Smoking' signs; and
(g) Structural fire protection as required by *Table 3.3.2 Fire integrity of bulkheads separating adjacent spaces* and *Table 3.3.3 Fire integrity of decks separating adjacent spaces*.

3.34.2 Such spaces are not to give access to any space other than the fuel store or lockers for use within the space. Lockers storing fuel are to be accessed from an exterior location, unless the locker is within the space containing the vehicles or craft. Exceptionally, where the engine room escape cannot be routed elsewhere, it may exit into the space providing that:

(a) the connecting door is self-closing;
(b) no door hold-back devices are fitted;
(c) an audible and visual alarm is fitted on the bridge to signify when the door is open; and
(d) a notice is posted at the door stating that the door is to remain closed and that the area beside the door is an escape route and is to be kept clear.

3.34.3 The requirements of *Pt 17, Ch 3, 3.17 Fuel oil arrangements* are to be complied with, as appropriate.

3.35 Protection of paint lockers and flammable liquid lockers

3.35.1 Paint lockers and flammable liquid lockers of deck area 4 m^2 or more are to be provided with a fixed fire-extinguishing system enabling the crew to extinguish a fire without entering the space. One of the following systems is to be provided:

- A carbon dioxide system designed for 40 per cent of the gross volume of the space.
- A dry powder system designed to discharge 0,5 kg powder per cubic metre of gross volume of the space.
- A water spray system designed to give a coverage of 5 litres per square metre of deck area per minute. Water spray systems may be connected to the fire main.

3.35.2 Consideration will be given to the acceptance of other arrangements which provide equivalent protection.

3.35.3 Lockers having a deck area of less than 4 m^2 may be protected by carbon dioxide or dry powder portable extinguishers located near the entrance to the locker.

3.36 Arrangements where deep fat cooking equipment is installed

3.36.1 Where deep-fat cooking equipment is installed, all installations are to fitted with:

(a) an automatic or manual fixed extinguishing system type approved in accordance with ISO 15371, *Ships and marine technology-Fire extinguishing systems for protection of galley deep-fat cooking equipment-Fire tests*, or an acceptable alternative National or International Standard, for protection of the deep-fat cooking equipment;
(b) a primary and back up thermostat with an alarm to alert the operator in the event of failure of either thermostat;
(c) arrangements for automatically shutting off the deep-fat cooking equipment electrical power upon activation of the fire-extinguishing system;
(d) an alarm for indicating operation of the fire-extinguishing system in the galley where the equipment is installed; and
(e) controls for manual operation of the fire-extinguishing system which are clearly labelled for ready use by the crew.

Control and electrical engineering arrangements are to be in accordance with the requirements of *Pt 16, Ch 1 Control Engineering Systems* and *Pt 16, Ch 2 Electrical Engineering*, as applicable.

3.36.2 For fryers of up to 15 litres cooking oil capacity, the provision of a suitably sized extinguisher of a suitable type located for specific use on the cooking equipment together with manual isolation of the electrical power supply may be considered an

acceptable alternative to *Pt 17, Ch 3, 3.36 Arrangements where deep fat cooking equipment is installed 3.36.1* provided the arrangements are to the satisfaction of the National Administration.

3.37 Helicopter decks

3.37.1 The requirements of *IMO Resolution A.855(20) – Standards for On-Board Helicopter Facilities – (Adopted on 27 November 1997)* are to be complied with having due regard to the hazards involved.

3.37.2 If a helicopter hangar is not provided and if two fireman's outfits are supplied as per *Pt 17, Ch 3, 3.38 Fireman's outfit 3.38.1*, then the fireman's outfits required by *IMO Resolution A.855(20) – Standards for On-Board Helicopter Facilities – (Adopted on 27 November 1997)* need not be provided.

3.38 Fireman's outfit

3.38.1 Each yacht is to carry at least two fireman's outfits complying with *Pt 17, Ch 4, 4 Fireman's outfits*. Additional fireman's outfits are to be provided as applicable to ensure that at least two fireman's outfits are stored in each main vertical zone.

3.38.2 The fireman's outfits are to be so stored as to be easily accessible and ready for use. Where more than two fireman's outfits are required, they are to be located in widely separated positions. At least two fireman's outfits are to be available at any one position.

3.38.3 Additional sets of personal equipment and breathing apparatus may be required, having due regard to the size of the yacht.

3.39 Fire-control plans

3.39.1 Fire-control plans are to meet the requirements of *Pt 17, Ch 4, 5 Fire-control plans*.

Section

■ *Section 1* Automatic sprinkler, fire detection and fire-alarm systems

1.1 General

1.1.1 Any required automatic water sprinkler and fire-alarm and fire detection system is to be designed for immediate use at any time. Where such a system is fitted, it is to be of the wet pipe type. Any part of the system which may be subjected to freezing temperatures in service is to be suitably protected against freezing. It is to be kept charged at the necessary pressure and have provision for a continuous supply of water.

1.1.2 As an alternative to the system specified in *Pt 17, Ch 4, 1.1 General 1.1.1*, any one of the following systems may be considered:

(a) **Dry pipe system**. A sprinkler system employing automatic sprinklers attached to a piping system containing air or nitrogen under pressure, the release of which (as from the opening of a sprinkler) permits the water pressure to open a valve known as a dry pipe valve. The water then flows into the piping system and out of the opened sprinklers.

(b) **Pre-action system**. A sprinkler system employing automatic sprinklers attached to a piping system containing air that may or may not be under pressure, with a supplemental detection system installed in the same area as the sprinklers. Actuation of the detection system opens a valve that permits water to flow into the sprinkler piping system and to be discharged from any sprinklers that may be open.

(c) **Deluge system**. A sprinkler system employing open sprinklers attached to a piping system connected to a water supply through a valve that is opened by the operation of a detection system installed in the same areas as the sprinklers. When this valve opens water flows into the piping system and discharges from all sprinklers attached thereto.

1.2 Wet pipe type

1.2.1 Any required automatic sprinkler, fire detection and fire-alarm system is to comply with the requirements of *Pt 16, Ch 2, 17.2 Automatic sprinkler, fire detection and fire alarm systems* .

1.2.2 Sprinklers are to be grouped into separate sections, each of which is to contain not more than 200 sprinklers. Any section of sprinklers is not to serve more than two decks nor be situated in more than one main vertical zone, except where it is satisfactorily shown that the protection of the yacht against fire will not thereby be reduced.

1.2.3 Each section of sprinklers is to be capable of being isolated by one stop valve only. The stop valve in each section is to be readily accessible and its location is to be clearly and permanently indicated. Means are to be provided to prevent the operation of the stop valves by any unauthorised person.

1.2.4 A gauge indicating the pressure in the system is to be provided at each section stop valve and at a central station.

1.2.5 The sprinklers are to be resistant to corrosion by marine atmosphere. In accommodation and service spaces the sprinklers are to come into operation within the temperature ranges from 68°C to 79°C, except that in locations such as drying rooms, where high ambient temperatures might be expected, the operating temperature may be increased by not more than 30°C above the maximum deck head temperature.

1.2.6 A list or plan is to be displayed at each indicating unit showing the spaces covered and the location of the zone in respect of each section. Suitable instructions for testing and maintenance are to be available.

1.2.7 Sprinklers are to be placed in an overhead position and spaced in a suitable pattern to maintain an average application rate of not less than 5 litres per square metre per minute over the nominal area covered by the sprinklers. For this purpose, the nominal area shall be taken as the gross horizontal projection of the area to be covered. The use of sprinklers providing other amounts of water suitably distributed, will be considered provided they are shown to be not less effective.

1.2.8 A pressure tank having a volume equal to at least twice that of the charge of water specified in *Pt 17, Ch 4, 1.2 Wet pipe type 1.2.9* is to be provided.

1.2.9 The tank is to contain a standing charge of fresh water, equivalent to the amount of water which would be discharged in one minute by the pump referred to in *Pt 17, Ch 4, 1.2 Wet pipe type 1.2.12*, and the arrangements are to provide for maintaining such air pressure in the tank to ensure that where the standing charge of fresh water in the tank has been used the pressure will be not less than the working pressure of the sprinkler, plus the pressure exerted by a head of water measured from the bottom of the tank to the highest sprinkler in the system. Suitable means of replenishing the air under pressure and of replenishing the fresh water charge in the tank are to be provided. A glass gauge suitably protected is to be provided to indicate the correct level of the water in the tank.

1.2.10 Means are to be provided to prevent the passage of sea water into the tank.

1.2.11 An independent power pump is to be provided solely for the purpose of automatically continuing the discharge of water from the sprinklers. The pump is to be brought into action automatically by the pressure drop in the system before the standing fresh water charge in the pressure tank is completely exhausted.

1.2.12 The pump and the piping system are to be capable of maintaining the necessary pressure at the level of the highest sprinkler to ensure a continuous output of water sufficient for the simultaneous coverage of a minimum area of the maximum width of the craft squared or 280 m^2 whichever is less, at the application rate specified in *Pt 17, Ch 4, 1.2 Wet pipe type 1.2.7*.

1.2.13 The pump is to have fitted on the delivery side a test valve with a short open-ended discharge pipe. The effective area through the valve and pipe is to be adequate to permit the release of the required pump output while maintaining the pressure in the system specified in *Pt 17, Ch 4, 1.2 Wet pipe type 1.2.9*.

1.2.14 The sea inlet to the pump is to be, wherever possible, in the space containing the pump and is to be so arranged that when the vessel is afloat it will not be necessary to shut off the supply of sea water to the pump for any purpose other than the inspection or repair of the pump.

1.2.15 The sprinkler pump and tank are to be situated in a position reasonably remote from any machinery space of Category `A' and not in any space required to be protected by the sprinkler system.

1.2.16 Where the arrangement precludes locating the pump and tank in accordance with *Pt 17, Ch 4, 1.2 Wet pipe type 1.2.15*, for yachts not greater than 50 m Rule length, the sprinkler pump and tank required by *Pt 17, Ch 3, 2.16 Automatic sprinkler, fire detection and fire-alarm system* may be situated within Category ‘A' machinery spaces, but not within the spaces that are protected by the system.

1.2.17 For yachts of not greater than 50 m Rule length and all service craft, the sources of electrical power supply for the sea-water pump may be fed from the main source of electrical power.

1.2.18 There are to be not less than two sources of power supply for the sea water pump and automatic alarm and detection system. Where one of the sources of power for the pump is an internal combustion engine it is to be so situated that a fire in any protected space will not affect the air supply to the machinery, in addition to complying with *Pt 17, Ch 4, 1.2 Wet pipe type 1.2.15*. When the sources of power for the pump are electrical, *see Pt 16, Ch 2, 2 Main source of electrical power* and *Pt 16, Ch 2, 3 Emergency source of electrical power*.

1.2.19 The sprinkler system is to have a connection from the vessel's fire main by way of a lockable screw-down non-return valve at the connection which will prevent a backflow from the sprinkler system to the fire main.

1.2.20 A test valve is to be provided for testing the automatic alarm for each section of sprinklers by a discharge of water equivalent to the operation of one sprinkler. The test valve for each section is to be situated near the stop valve for that section.

1.2.21 Means are to be provided for testing the automatic operation of the pump, on reduction of pressure in the system.

1.2.22 Each section of sprinklers is to include means for giving a visual and audible alarm signal automatically at one or more indicating units whenever any sprinkler comes into operation. Such alarm systems are to be such as to indicate if any fault occurs in the system. Such units are to indicate in which section, served by the system, fire has occurred and are to be centralised on the navigation bridge. In addition, visible and audible alarms from the unit are to be located in a position other than on the navigation bridge, so as to ensure that the indication of fire is immediately received by the crew. Switches are to be provided at one of these indicating positions, which will enable the alarm and the indicators for each section of sprinklers to be tested.

1.2.23 Spare sprinkler heads are to be provided as specified in *Table 4.1.1 Spares requirements*. The spare sprinkler heads are to be stowed in boxes or holders provided for that purpose, together with a tool suitable for removing and installing sprinkler heads. The boxes or holders are to be situated near the control valve for the section, and are to be clearly and permanently marked to indicate their contents.

Table 4.1.1 Spares requirements

Number of sprinkler heads provided	Number of spare sprinkler heads required
300	One spare sprinkler head is to be provided for each 50 sprinkler heads fitted, with a minimum of one spare being provided for each type fitted
301 to 1000	12
>1000	24

1.3 Arrangements which will be accepted as an alternative to 1.2

1.3.1 The alternative system is to be tested, type approved and installed in accordance with *IMO Resolution A.800(19) – Revised Guidelines for Approval of Sprinkler Systems Equivalent to that Referred to in SOLAS Regulation II-2/12 – (Adopted on 23 November 1995)*. The following exceptions to Section 3 of the Annex may be applied:

(a) Where the arrangement precludes locating the pump and tank in accordance with *Pt 17, Ch 4, 1.2 Wet pipe type 1.2.15*, for yachts not greater than 50 m Rule length, the sprinkler pump and tank required by *Pt 17, Ch 3, 2.16 Automatic sprinkler, fire detection and fire-alarm system* may be situated within Category 'A' machinery spaces, but not within the spaces that are protected.

(b) Pumps and alternative supply components are to be sized so as to be capable of maintaining the required flow to the hydraulically most demanding area of not less than the maximum width of the craft squared or 280 m^2 whichever is the less.

1.3.2 Spare nozzles are to be provided as specified in *Table 4.1.2 Spares requirements*. The spare nozzles are to be stowed in boxes or holders provided for that purpose, together with a tool suitable for removing and installing nozzles. The boxes or holders are to be situated near the control valve for the section, and are to be clearly and permanently marked to indicate their contents.

Table 4.1.2 Spares requirements

Number of nozzles provided	Number of spare nozzles required
300	One spare nozzle is to be provided for each 50 nozzles fitted, with a minimum of one spare being provided for each type fitted
301 to 1000	12
>1000	24

Section 2
Fixed fire detection and fire-alarm systems

2.1 General requirements

2.1.1 Any required fixed fire detection and fire-alarm system with manually operated call points is to be capable of immediate operation at all times.

2.1.2 Fire detection systems are to comply with the requirements of *Pt 16, Ch 2, 17.1 Fire detection and fire alarm systems* in addition to the requirements of this Section.

2.1.3 Detectors are to be operated by heat, smoke or other products of combustion, flame, or any combination of these factors. Detectors operated by other factors indicative of incipient fires may be considered provided that they are no less sensitive than such detectors. Flame detectors are only to be used in addition to smoke or heat detectors.

2.1.4 Suitable instructions for testing and maintenance are to be provided.

2.1.5 For each type of detector installed, one spare detector head is to be provided for every 10 heads or part thereof. They are to be stowed in a suitable container at the control station.

2.1.6 The function of the detection system is to be periodically tested by means of equipment producing hot air at the appropriate temperature, or smoke or aerosol particles having the appropriate range of density or particle size, or other phenomena associated with incipient fires to which the detector is designed to respond. All detectors are to be of a type such that they can be tested for correct operation and restored to normal surveillance without the renewal of any component.

2.2 Installation requirements

2.2.1 Manually operated call points are to be installed throughout the accommodation spaces, service spaces and control stations. One manually operated call point is to be located at each exit. Manually operated call points are to be readily accessible in the corridors of each deck such that no part of the corridor is more than 20 m from a manually operated call point.

2.2.2 Smoke detectors are to be installed in all stairways, corridors and escape routes within accommodation spaces.

2.2.3 Where a fixed fire detection and fire-alarm system is required for the protection of spaces other than those specified in *Pt 17, Ch 4, 2.2 Installation requirements 2.2.2*, at least one detector complying with *Pt 17, Ch 4, 2.1 General requirements 2.1.3*, is to be installed in each such space.

2.2.4 Detectors are to be located for optimum performance. Positions near beams and ventilation ducts or other positions where patterns of air flow could adversely affect performance and positions where impact or physical damage is likely are to be avoided. In general, detectors which are located overhead are to be a minimum distance of 0,5 m away from bulkheads.

2.2.5 The maximum spacing of detectors is to be in accordance with *Table 4.2.1 Maximum spacing of detectors*. Other spacings based upon test data which demonstrate the characteristics of the detectors may be required or permitted.

Table 4.2.1 Maximum spacing of detectors

Maximum		Maximum	
Maximum floor		distance apart between centres, in metres	distance away from bulkheads, in metres
Type of detector	area per detector, m^2		
Heat	37	9	4,5
Smoke	74	11	5,5

2.2.6 Electrical wiring which forms part of the system is to be so arranged as to avoid galleys, machinery spaces of Category `A', and other enclosed spaces of high fire-risk except where it is necessary to provide for fire detection or fire-alarm in such spaces or to connect to the appropriate power supply. *See also Pt 16, Ch 2 Electrical Engineering*.

2.3 Design requirements

2.3.1 Smoke detectors required by *Pt 17, Ch 4, 2.2 Installation requirements 2.2.2* are to be certified to operate before the smoke density exceeds 12,5 per cent obscuration per metre, but not until the smoke density exceeds two per cent obscuration per metre. Smoke detectors to be installed in other spaces are to operate within satisfactory sensitivity limits having regard to the avoidance of detector insensitivity or oversensitivity.

2.3.2 Heat detectors are to be certified to operate before the temperature exceeds 78°C but not until the temperature exceeds 54°C, when the temperature is raised to those limits at a rate less than 1°C per minute. At higher rates of temperature rise, the heat detector is to operate within satisfactory temperature limits having regard to the avoidance of detector insensitivity or oversensitivity.

2.3.3 The permissible temperature of operation of heat detectors may be increased to 30°C above the maximum deckhead temperature in drying rooms and similar spaces of a normal high ambient temperature.

2.4 Requirements for machinery spaces

2.4.1 The arrangements of the fixed fire detection and fire-alarm system in machinery spaces are to comply with the requirements of *Pt 16, Ch 1, 2.8 Fire detection and fire alarm systems*.

■ *Section 3*
Fixed fire-extinguishing systems in machinery spaces

3.1 Gas fire-extinguishing systems

3.1.1 The use of a fire-extinguishing medium which, either by itself or under expected conditions of use, gives off toxic gases in such quantities as to endanger persons is not permitted.

3.1.2 New installations that use fire-extinguishing media, which have ozone-depleting properties under the Montreal Protocol, are not permitted.

3.1.3 The necessary pipes for conveying a fire-extinguishing medium into protected spaces are to be provided with control valves which are to be so placed that they will be easily accessible and not readily cut off from use by an outbreak of fire. The control valves are to be so marked as to indicate clearly the spaces to which the pipes are led. Suitable provision is to be made to prevent inadvertent admission of the medium to any space. Where pipes pass through accommodation spaces they are to be seamless and the number of pipe joints are to be kept to a minimum and made by welding.

3.1.4 The piping for the distribution of fire-extinguishing medium is to be of adequate size and so arranged, and discharge nozzles so positioned that a uniform distribution of medium is obtained. All pipes are to be arranged to be self draining and where led into refrigerated spaces, the arrangement will be specially considered. A means whereby the individual pipes to all protected spaces can be tested using compressed air is to be provided. Distribution pipes are to extend at least 50 mm beyond the last nozzle.

3.1.5 Steel pipes fitted in spaces where corrosion is likely to occur are to be galvanised, at least internally.

3.1.6 Distribution pipes for carbon dioxide are not to be smaller than 20 mm bore.

3.1.7 Means are to be provided to close all openings which may admit air into, or allow gas to escape from, a protected space.

3.1.8 The volume of starting air receivers, converted to free air volume, is to be added to the gross volume of the machinery space when calculating the necessary quantity of extinguishing medium. Alternatively a discharge pipe from the safety valves may be fitted and led directly to the open air.

3.1.9 Means are to be provided for automatically giving audible and visual warning of the release of fire-extinguishing medium into any space in which personnel normally work or to which they have access. The alarm is to operate for a suitable period before the medium is released.

3.1.10 Where pneumatically operated alarms are fitted which require periodic testing, carbon dioxide is not to be used as an operating medium. Air operated alarms may be used provided that the air supply is clean and dry.

3.1.11 Where electrically operated alarms are used, the arrangements are to be such that the electric operating mechanism is located outside hazardous spaces.

3.1.12 The means of control of any fixed gas fire-extinguishing system is to be readily accessible and simple to operate and shall be grouped together in as few locations as possible at positions not likely to be cut off by a fire in a protected space. At each location there is to be clear instructions relating to the operation of the system having regard to the safety of personnel. Two separate controls are to be provided for releasing carbon dioxide into a protected space and each is to ensure the activation of the alarm. One control is to be used to discharge the gas from its storage cylinder(s). A second control is to be used for opening the valve of the piping which conveys the gas into the protected space. The two controls are to be located inside a release box clearly identified for the particular space. If the box containing the controls is to be locked, a key to the box is to be in a break-glass type enclosure conspicuously located adjacent to the box. There is to be a dedicated release box for each protected space, in which personnel normally work or to which they have access, *see also Pt 17, Ch 4, 3.1 Gas fire-extinguishing systems 3.1.9*. The space served is to be identified at the release box.

3.1.13 Automatic release of fire-extinguishing medium is not permitted.

3.1.14 Where the quantity of extinguishing medium is required to protect more than one space, the quantity of medium available need not be more than the largest quantity required for any one space so protected. Adjacent spaces with independent ventilation systems not separated by at least A-0 class divisions are to be considered as the same space.

3.1.15 Means are to be provided for the crew to safely check the quantity of medium in the containers. It shall not be necessary to move the containers completely from their fixing position for this purpose. For carbon dioxide systems, hanging bars for a weighing device above each bottle row, or other means shall be provided. For other types of extinguishing media, suitable surface indicators may be used.

3.1.16 Containers for the storage of fire-extinguishing media and associated pressure components are to be designed and tested to Codes of Practice recognised by LR having regard to their locations and the maximum ambient temperatures expected in service.

3.1.17 The fire-extinguishing medium is to be stored outside a protected space, in a room which is situated in a safe and readily accessible position and effectively ventilated. Any entrance to such a storage room is to preferably be from the open deck and in any case be independent of the protected space. Access doors are to open outwards, and bulkheads and decks including doors and other means of closing any opening therein, which form the boundaries between such rooms and adjoining enclosed spaces are to be gastight. Such storage rooms are to be treated as control stations.

3.1.18 In systems where containers discharge into a common manifold, non-return valves are to be provided at the connections of the container discharge pipes to the manifold to allow any container to be disconnected without preventing the use of other containers in the system and to prevent the discharge of extinguishing medium into the container storage room in the event of the system being operated. Manifolds are to be tested by hydraulic pressure to 1,5 times the design pressure. The design pressure is the maximum gauge pressure to which the system may be subjected and is not to be less than the gauge pressure corresponding to the maximum ambient temperature expected in service. The design pressure need not be greater than the maximum setting of the manifold pressure relief valve. After the hydraulic test, manifolds are to be carefully cleaned and dried before the non-return valves are finally fitted.

3.1.19 For craft on unrestricted service, spare parts for the system are to be stored on board. As a minimum these are to consist of:

- 1 actuator;
- 1 flexible hose (cylinder to manifold); and
- the cylinder bursting discs and sealing washers for all cylinders.

3.2 Carbon dioxide systems

3.2.1 Carbon dioxide systems are to comply with *Pt 17, Ch 4, 3.1 Gas fire-extinguishing systems* in addition to the remaining requirements of this sub-Section.

3.2.2 For the purpose of this paragraph the volume of free carbon dioxide is to be calculated at 0,56 m^3/kg.

3.2.3 For machinery spaces:

(a) The quantity of carbon dioxide carried is to be sufficient to give a minimum volume of free gas equal to the larger of:

- 40 per cent of the gross volume of the largest machinery space so protected, the volume to exclude that part of the casing above the level at which the horizontal area of the casing is 40 per cent or less of the horizontal area of the space concerned taken midway between the tank top and the lowest part of the casing; or

- 35 per cent of the gross volume of the largest machinery space protected, including the casing.

(b) The above mentioned percentages may be reduced to 35 per cent and 30 per cent respectively for craft less than 2000 gross tons.

(c) The fixed piping system is to be such that 85 per cent of the gas can be discharged into the space within two minutes.

(d) The distribution arrangements are to be such that approximately 15 per cent of the required quantity of carbon dioxide is led to the bilge areas.

3.2.4 Two separate controls are to be provided for releasing carbon dioxide into a protected space and each is to ensure the activation of the alarm. One control is to be used to discharge the gas from its storage cylinder(s). A second control is to be used for opening the valve of the piping which conveys the gas into the protected space. The two controls are to be located inside a release box clearly identified for the particular space. If the box containing the controls is to be locked, a key to the box is to be in a break-glass type enclosure conspicuously located adjacent to the box. There is to be a dedicated release box for each protected space in which personnel normally work or to which they have access, *see also Pt 17, Ch 4, 3.1 Gas fire-extinguishing systems 3.1.8*. The space served is to be identified at the release box.

3.3 High-expansion foam systems

3.3.1 Any required fixed high-expansion foam system in machinery spaces is to be capable of rapidly discharging through fixed discharge outlets a quantity of foam sufficient to fill the greatest space to be protected at a rate of at least 1 m in depth per minute. The quantity of foam-forming liquid available is to be sufficient to produce a volume of foam equal to five times the volume of the largest space to be protected.

3.3.2 The expansion ratio of the foam is not to exceed 1000 to 1.

3.3.3 Alternative arrangements and discharge rates will be permitted provided that equivalent protection is achieved.

3.3.4 Supply ducts for delivering foam, air intakes to the foam generator and the number of foam producing units are to be such as will provide effective foam production and distribution.

3.3.5 The arrangement of the foam generator delivery ducting is to be such that a fire in the protected space will not affect the foam-generating equipment.

3.3.6 The foam generator, its sources of power supply, foam-forming liquid and means of controlling the system are to be readily accessible and simple to operate and are to be grouped in as few locations as possible at positions not likely to be cut off by fire in the protected space. Such stations are to be treated as control stations.

3.3.7 Foam concentrates are to be of an approved type.

3.4 Pressure water-spraying systems

3.4.1 Any required fixed pressure water-spraying fire-extinguishing system in machinery spaces is to be provided with spraying nozzles of an approved type.

3.4.2 The number and arrangement of the nozzles is to be such as to ensure an effective average distribution of water of at least five litres per square metre per minute in the spaces to be protected. Where increased application rates are considered necessary, these will be specially considered. Nozzles are to be fitted above bilges, tank tops and other areas over which fuel oil is liable to spread and also above other specific fire hazards in the machinery spaces.

3.4.3 The system may be divided into sections, the distribution valves of which are to be operated from easily accessible positions outside the spaces to be protected and which will not be readily cut off by fire in the protected space.

3.4.4 The system is to be kept charged at the necessary pressure, and the pump supplying the water for the system is to be put automatically into action by a pressure drop in the system.

3.4.5 The pump is to be capable of simultaneously supplying, at the necessary pressure, all sections of the system in any one compartment to be protected. The pump and its controls are to be installed outside the space or spaces to be protected. It is not to be possible for a fire in the space or spaces protected by the water-spraying system to put the system out of action.

3.4.6 The pump may be driven by independent internal combustion type machinery but if it is dependent upon power being supplied from the emergency generator, that generator is to be arranged to start automatically in case of main power failure so that power for the pump required by *Pt 17, Ch 4, 3.4 Pressure water-spraying systems 3.4.5* is immediately available. When the pump is driven by independent internal combustion machinery it is to be so situated that a fire in the protected space will not affect the air supply to the machinery.

3.4.7 Precautions are to be taken to prevent the nozzles from becoming clogged by impurities in the water or corrosion of the piping, nozzles, valves and pump.

3.5 Arrangements which will be accepted as alternatives to 3.4

3.5.1 The system is to be tested, type approved and installed in accordance with *MSC/Circular.668 – Alternative Arrangements For Halon Fire-extinguishing Systems In Machinery Spaces And Pump-rooms – (Adopted on 22 December 1994)Amended by MSC/Circular.728* as amended by *MSC/Circular.728 – Revised Test Method for Equivalent Water-Based Fire-Extinguishing Systems for Machinery Spaces of Category A and Cargo Pump-Rooms contained in MSC/Circular.668 – (Adopted on 4 July 1996)*.

3.6 Other systems

3.6.1 Other fixed fire-extinguishing systems will be specially considered.

3.6.2 The use of steam as a fire-extinguishing medium in fixed fire-extinguishing systems is not permitted.

■ *Section 4* Fireman's outfits

4.1 Components

4.1.1 A fireman's outfit is to consist of:

(a) Personal equipment comprising:

- (i) Protective clothing of material to protect the skin from the heat radiating from the fire and from burns and scalding by steam. The outer surface is to be water-resistant.
- (ii) Boots and gloves of rubber or other electrically non-conducting material.
- (iii) A rigid helmet providing effective protection against impact.
- (iv) An electric safety lamp (hand lantern) of an approved type with a minimum burning period of three hours.
- (v) An axe with an insulated handle.

(b) A self-contained breathing apparatus of an approved type. The volume of air contained in the cylinders of which is to be at least 1200 litres or other self-contained breathing apparatus which is to be capable of functioning for a period of at least 30 minutes. Spare bottles are to be provided which are to be maintained fully charged except where facilities for re-charging the bottles are available on board. At least two spare charges for each breathing apparatus are to be provided, and all air cylinders for breathing apparatus are to be interchangeable.

4.1.2 For each breathing apparatus a fireproof life-line of sufficient length and strength is to be provided capable of being attached by means of a snaphook to the harness of the apparatus or to a separate belt in order to prevent the breathing apparatus becoming detached when the life-line is operated.

■ *Section 5* Fire-control plans

5.1 Description of plans

5.1.1 General arrangement plans are to be permanently exhibited for the guidance of the ship's officers, using graphical symbols that are in accordance with *IMO Resolution A.654(16) – Graphical Symbols for Fire Control Plans – (Adopted on 19 October 1989)*, which show clearly for each deck the control stations, the various fire sections enclosed by steel or 'A' and 'B' Class divisions, together with particulars of:

- the fire detection and fire-alarm system;
- any sprinkler installation;
- the fire-extinguishing appliances;

- the means of access to different compartments, decks, etc.;
- the position of the fireman's outfits;
- the ventilating system, including particulars of the fan control positions, the position of dampers and identification numbers of the ventilating fans serving each section; and
- the location and arrangement of the emergency stop(s) for pumps, and for remote closing the valves on the pipes from tanks, for fuel oil, lubricating oil and other flammable oils.

5.1.2 Alternatively, the details required by *Pt 17, Ch 4, 5.1 Description of plans 5.1.1* may be set out in a booklet, a copy of which is to be supplied to each officer, and one copy is at all times to be available on board in an accessible position.

5.1.3 The plans and booklets are to be kept up to date, any alterations being recorded thereon as soon as practicable. Description in such plans and booklets is to be in the official language of the flag state. If the language is neither English nor French, a translation into one of those languages is to be included. In addition, instructions concerning the maintenance and operation of all the equipment and installations on board for the fighting and containment of fire are to be kept under one cover, readily available in an accessible position.

5.1.4 A duplicate set of fire-control plans or a booklet containing such plans is to be permanently stored in a prominently marked weathertight enclosure outside the deckhouse for the assistance of shoreside fire-fighting personnel.

■ *Section 6*
Fire-extinguishers (portable and non-portable)

6.1 Approved types

6.1.1 All fire-extinguishers are to be of approved types and designs.

6.2 Extinguishing medium

6.2.1 The extinguishing media employed are to be suitable for extinguishing fires in the compartments in which they are intended to be used.

6.2.2 The extinguishers required for use in the machinery spaces using oil as fuel are to be of a type suitable for extinguishing oil fires.

6.2.3 Fire-extinguishers containing an extinguishing medium which, either by itself or under expected conditions of use, gives off toxic gases in such quantities as to endanger persons, are not permitted.

6.3 Capacity

6.3.1 The capacity of required portable fluid extinguishers is to be not more than 13,5 litres but not less than nine litres. Other extinguishers are to be at least as portable as the 13,5 litre fluid extinguishers and are to have a fire-extinguishing capability at least equivalent to a 9,0 litre fluid extinguisher.

6.3.2 The following capacities may be taken as equivalents:

- 9 litre fluid extinguisher;
- 4,5 kg dry powder;
- 5 kg carbon dioxide.

6.4 Spare charges

6.4.1 A spare charge is to be provided for each required portable fire-extinguisher which can be readily re-charged on board. If this cannot be done, duplicate extinguishers are to be provided.

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